STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF WATER RESOURCES

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR E. COLI IN WATAUGA RIVER WATERSHED (HUC 06010103), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Load (TMDL) for E. coli in the Watauga River watershed, located in eastern Tennessee. Section 303(d) of the Clean Water Act requires states to develop TMDLs for waters on their impaired waters list. TMDLs must determine the allowable pollutant load that the water can assimilate, allocate that load among the various point and nonpoint sources, include a margin of safety, and address seasonality.

A number of waterbodies in the Watauga River watershed are listed on Tennessee's Proposed Final 2014 303(d) list as not supporting designated use classifications due, in part, to pasture grazing. The TMDL utilizes Tennessee's general water quality criteria, continuous flow data from a USGS discharge monitoring station located in proximity to the watershed, site specific water quality monitoring data, a calibrated hydrologic model, load duration curves, and an appropriate Margin of Safety (MOS) to establish allowable loadings of pathogens which will result in the reduced in-stream concentrations and attainment of water quality standards. The TMDL requires reductions of E. coli loading on the order of 51.0-99.7% in the listed waterbodies.

The Watauga River E. coli TMDL may be downloaded from the Department of Environment and Conservation website:

http://www.tn.gov/environment/water/water-quality_total-daily-maximum-loads.shtml

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Resources staff:

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Persons wishing to comment on the proposed TMDLs are invited to submit their comments in writing no later than May 26, 2015 to:

Department of Environment and Conservation
Division of Water Resources
Watershed Management Unit
William R. Snodgrass Tennessee Tower
312 Rosa L. Parks Avenue, 11th Floor
Nashville, TN 37243

All comments received prior to that date will be considered when revising the TMDL for final submittal to the U.S. Environmental Protection Agency.

The TMDL and supporting information are on file at the Division of Water Resources, William R. Snodgrass Tennessee Tower, 312 Rosa L. Parks Avenue, 11th Floor, Nashville, Tennessee 37243. They may be inspected during normal office hours. Copies of the information on file are available on request.

PROPOSED
TOTAL MAXIMUM DAILY LOAD (TMDL)

for

E. Coli

in the

Watauga River Watershed

(HUC 06010103)

Carter, Johnson, Sullivan, Unicoi and Washington Counties, Tennessee

Draft

Prepared by:

Tennessee Department of Environment and Conservation
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312 Rosa L. Parks Avenue, 11th Floor
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April 13, 2015

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

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LIST OF ABBREVIATIONS

ADB	Assessment Database
AFO	Animal Feeding Operation
BMP	Best Management Practices
BST	Bacteria Source Tracking
BWP	Boone Watershed Partnership
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CFU	Colony Forming Units
CSO	Combined Sewer Overflow
DA	Drainage Area
DEM	Digital Elevation Model
DWR	Division of Water Resources
E. coli	Escherichia coli
EPA	Environmental Protection Agency
GIS	Geographic Information System
GM	Geomean
HSPF	Hydrological Simulation Program - Fortran
HUC	Hydrologic Unit Code
LA	Load Allocation
LCS	Leaking Collection System
LDC	Load Duration Curve
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NGD	No geomean data
NHD	National Hydrography Dataset
NMP	Nutrient Management Plan
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
PCR	Polymerase Chain Reaction
PDFE	Percent of Days Flow Exceeded
PFGE	Pulsed Field Gel Electrophoresis
PLRG	Percent Load Reduction Goal
q_d	Facility (WWTP) design flow (cfs)
q_m	Mean daily facility (WWTP) flow (cfs)
Q	Mean daily in-stream flow (cfs)
RM	River Mile
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
SWMP	Storm Water Management Program
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment & Conservation
TDOT	Tennessee Department of Transportation
TMDL	Total Maximum Daily Load
TWRA	Tennessee Wildlife Resources Agency

LIST OF ABBREVIATIONS (cont'd)

UCF	Unit Conversion Factor
USGS	United States Geological Survey
UTK	University of Tennessee – Knoxville
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTP	Wastewater Treatment Plant

SUMMARY SHEET

Total Maximum Daily Load for E. coli in Watauga River Watershed (HUC 06010103)

Impaired Waterbody Information

State: Tennessee
Counties: Carter, Johnson, Sullivan, Unicoi, and Washington
Watersheds: Watauga River (HUC 06010103)
Constituents of Concern: E. coli
Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	Miles Impaired
TN06010103001T-0100	Darr Creek	3.85
TN06010103006-0100	Carroll Creek	4.3
TN06010103006-1000	Boones Creek	19.31
TN06010103008-0400	Davis Branch	5.9
TN06010103008-0800	Gap Creek	15.93
TN06010103009-1000	Brush Creek	20.3
TN06010103011-0100	Powder Branch	6.2
TN06010103011-0200	Toll Branch	6.5
TN06010103011-1000	Buffalo Creek (from Watauga River to Unicoi County line	6.08
TN06010103020T-0200	Sink Branch	3.14
TN06010103034-0300	Town Creek	3.0
TN06010103034-2000	*Roan Creek (from Mill Creek to Lumpkin Branch)*	*6.0*
TN06010103046-1000	Sinking Creek	10.0
TN06010103061-1000	Reedy Creek	10.7
TN06010103635-0100	Cash Hollow Creek	3.48
TN06010103635-0200	Cobb Creek	4.5
TN06010103635-1000	Knob Creek	12.3

* Maximum water quality target is 487 CFU/100 mL for lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters waterbodies and 941 CFU/100 mL for other waterbodies. Waterbodies utilizing the 487 CFU/100 mL target are italicized.

Designated Uses:

The designated use classifications for waterbodies in the Watauga River Watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Buffalo Creek and Gap Creek are designated as trout streams. All of Roan Creek is also designated as either a trout stream or a naturally reproducing trout stream. Roan Creek (except for mile 16.7 to 17.7 in Mountain City) is designated for domestic water supply and industrial water supply. Roan Creek (except for mile 16.7 to 17.7 in Mountain City) is also classified as an Exceptional Tennessee Water. The portions of Gap Creek and Davis Branch that flow through the Cherokee National Forest are classified as Exceptional Tennessee Waters. None of the other impaired waterbodies in the Watauga River Watershed are classified as Exceptional Tennessee Waters.

Water Quality Targets:

Derived from *State of Tennessee Water Quality Standards, Chapter 0400-40-03, General Water Quality Criteria, 2013 Version* for recreation use classification (most stringent):

> The concentration of the E. coli group shall not exceed 126 colony forming units per 100 mL, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 mL shall be considered as having a concentration of 1 per 100 mL.
>
> Additionally, the concentration of the E. coli group in any individual sample taken from a lake, reservoir, State Scenic River, Exceptional Tennessee Water or ONRW (1200-4-3-.06) shall not exceed 487 colony forming units per 100 mL. The concentration of the E. coli group in any individual sample taken from any other waterbody shall not exceed 941 colony forming units per 100 mL.

For further information on Tennessee's general water quality standards, see:

http://www.tn.gov/sos/rules/0400/0400-40/0400-40-03.20131216.pdf

TMDL Scope:

Waterbodies identified on the Proposed Final 2014 303(d) list as impaired due to E. coli. TMDLs were developed for impaired waterbodies on a HUC-12 subwatershed or waterbody drainage area basis.

The E. coli TMDLs developed in this document supersede the pathogen TMDLs approved by the U.S. Environmental Protection Agency (EPA) in 2006 for selected waterbodies in the Watauga River watershed.

Analysis/Methodology:

The TMDLs for the impaired waterbodies in the Watauga River watershed were developed using a load duration curve methodology to assure compliance with the E. coli 126 CFU/100 mL geometric mean and the 487 CFU/100 mL maximum water quality criteria for lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters and 941 CFU/100 mL maximum water quality criterion for all other waterbodies. A duration curve is a cumulative frequency graph that represents the percentage of time during which the value of a given parameter is equaled or exceeded. Load duration curves are developed from flow duration curves and can illustrate existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the region of the waterbody flow zone represented by these existing loads. Load duration curves were also used to determine percent load reduction goals (PLRG) to meet the target maximum loading for E. coli.

Critical Conditions:

Water quality data collected over the most recent 5 year period for load duration curve analysis were used to assess the water quality standards representing a range of hydrologic and meteorological conditions.

For each impaired waterbody, critical conditions were determined by evaluating the percent load reduction goals and the percent of samples exceeding TMDL target concentrations (percent exceedance), for each hydrologic flow zone, to meet the target (TMDL) loading for E. coli. The percent load reduction goal and/or the percent exceedance of the greatest magnitude corresponds with the critical flow zone(s).

When available, water quality data collected over a period of up to 15 years were evaluated for determination of relative change (trend analysis).

Seasonal Variation:

The 10-year period used for WinHSPF model simulation and for load duration curve analysis included all seasons and a full range of flow and meteorological conditions.

Margin of Safety (MOS):

Explicit MOS = 10% of the E. coli water quality criteria for each impaired subwatershed or drainage area.

Summary of TMDLs, WLAs, & LAs expressed as daily loads for the Impaired Waterbodies in the Watauga River Watershed (HUC 06010103)

Impaired Waterbody Name	Impaired Waterbody ID	HUC-12 Subwatershed (06010103___)	TMDL	MOS	WLAs		LAs [c]
					WWTPs [a]	MS4s [b,c]	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/d/ac]	[CFU/d/ac]
Town Creek	TN06010103034 - 0300	0101	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$2.3 \times 10^{10} \times q_m$	$(1.097 \times 10^{6} \times Q) - (7.592 \times 10^{5})$ [f]	$(1.097 \times 10^{6} \times Q) - (7.592 \times 10^{5})$
Roan Creek	TN06010103034 – 2000	0102/0104 [d]	$1.2 \times 10^{10} \times Q$	$1.2 \times 10^{9} \times Q$	$1.2 \times 10^{10} \times q_m$	$(1.846 \times 10^{5} \times Q) - (2.448 \times 10^{5})$ [f]	$(1.846 \times 10^{5} \times Q) - (2.448 \times 10^{5})$
Sink Branch	TN06010103020T - 0200	0306 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(2.262 \times 10^{7} \times Q) - (2.519 \times 10^{7} \times q_d)$ [e,f]	$(2.262 \times 10^{7} \times Q) - (2.519 \times 10^{7} \times q_d)$ [e]
Buffalo Creek	TN06010103011 - 1000	0502	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(8.297 \times 10^{5} \times Q) - (9.239 \times 10^{5} \times q_d)$ [e]	$(8.297 \times 10^{5} \times Q) - (9.239 \times 10^{5} \times q_d)$ [e]
Powder Branch	TN06010103011 - 0100	0502 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(6.701 \times 10^{6} \times Q) - (7.462 \times 10^{6} \times q_d)$ [e]	$(6.701 \times 10^{6} \times Q) - (7.462 \times 10^{6} \times q_d)$ [e]
Toll Branch	TN06010103011 - 0200	0502 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(7.880 \times 10^{6} \times Q) - (8.774 \times 10^{6} \times q_d)$ [e]	$(7.880 \times 10^{6} \times Q) - (8.774 \times 10^{6} \times q_d)$ [e]
Sinking Creek	TN06010103046 - 1000	0503 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(2.325 \times 10^{6} \times Q) - (2.588 \times 10^{6} \times q_d)$ [e]	$(2.325 \times 10^{6} \times Q) - (2.588 \times 10^{6} \times q_d)$ [e]
Brush Creek	TN06010103009 - 1000	0504	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(1.981 \times 10^{6} \times Q) - (2.206 \times 10^{6} \times q_d)$ [e]	$(1.981 \times 10^{6} \times Q) - (2.206 \times 10^{6} \times q_d)$ [e]
Davis Branch	TN06010103008 - 0400	0505 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(1.935 \times 10^{7} \times Q) - (2.154 \times 10^{7} \times q_d)$ [e]	$(1.935 \times 10^{7} \times Q) - (2.154 \times 10^{7} \times q_d)$ [e]
Gap Creek	TN06010103008 - 0800	0505 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(3.390 \times 10^{6} \times Q) - (3.775 \times 10^{6} \times q_d)$ [e]	$(3.390 \times 10^{6} \times Q) - (3.775 \times 10^{6} \times q_d)$ [e]
Knob Creek	TN06010103635 - 1000	0506	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(1.523 \times 10^{6} \times Q) - (1.696 \times 10^{6} \times q_d)$ [e]	$(1.523 \times 10^{6} \times Q) - (1.696 \times 10^{6} \times q_d)$ [e]
Cobb Creek	TN06010103635 - 0200	0506 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(7.094 \times 10^{6} \times Q) - (7.899 \times 10^{6} \times q_d)$ [e]	$(7.094 \times 10^{6} \times Q) - (7.899 \times 10^{6} \times q_d)$ [e]
Cash Hollow Creek	TN06010103635 - 0100	0506 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(1.145 \times 10^{7} \times Q) - (1.275 \times 10^{7} \times q_d)$ [e]	$(1.145 \times 10^{7} \times Q) - (1.275 \times 10^{7} \times q_d)$ [e]
Boones Creek	TN06010103006 - 1000	0507 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(1.862 \times 10^{6} \times Q) - (2.074 \times 10^{6} \times q_d)$ [e]	$(1.862 \times 10^{6} \times Q) - (2.074 \times 10^{6} \times q_d)$ [e]
Carroll Creek	TN06010103006 - 0100	0507 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(1.096 \times 10^{7} \times Q) - (1.220 \times 10^{7} \times q_d)$ [e]	$(1.096 \times 10^{7} \times Q) - (1.220 \times 10^{7} \times q_d)$ [e]

Summary Table (cont'd). TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Watauga River Watershed (HUC 06010103)

Impaired Waterbody Name	Impaired Waterbody ID	HUC-12 Subwatershed (06010103___)	TMDL	MOS	WLAs		LAs [c]
					WWTPs [a]	MS4s [b,c]	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/d/ac]	[CFU/d/ac]
Darr Creek	TN06010103001T - 0100	0508 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(1.065 \times 10^7 \times Q) - (1.186 \times 10^7 \times q_d)$ [e]	$(1.065 \times 10^7 \times Q) - (1.186 \times 10^7 \times q_d)$ [e]
Reedy Creek	TN06010103061 - 1000	0508 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(5.871 \times 10^6 \times Q) - (6.537 \times 10^6 \times q_d)$ [e]	$(5.871 \times 10^6 \times Q) - (6.537 \times 10^6 \times q_d)$ [e]

Notes: Q = Mean Daily In-stream Flow (cfs).
q_m = Mean Daily WWTP Discharge (cfs)
q_d = Facility (WWTP) Design Flow (cfs)

a. WLAs for WWTPs are expressed as E. coli loads (CFU/day). All current and future WWTPs must meet water quality standards as specified in their NPDES permit.
b. Applies to any MS4 discharge loading in the subwatershed. Future MS4s will be assigned waste load allocations (WLAs) consistent with load allocations (LAs) assigned to precipitation induced nonpoint sources. Compliance is achieved by meeting in-stream single-sample E. coli concentrations of ≤ 941 CFU/100 mL (or 487 CFU/100 mL for lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters). Delisting is achieved by meeting in-stream geomean sample E. coli concentrations of ≤ 126 CFU/100 mL.
c. WLAs and LAs expressed as a "per acre" load are calculated based on the drainage area at the pour point of the HUC-12 subwatershed or drainage area (see Table A-1). As regulated MS4 area increases (due to future growth and/or new MS4 designation), unregulated LA area decreases by an equivalent amount. The sum will continue to equal total subwatershed area.
d. Waterbody Drainage Area (DA) is not coincident with HUC-12(s).
e. No WWTPs currently discharging into or upstream of the waterbody. (Expression is future growth term for new WWTPs.)
f. No MS4s currently located in the subwatershed drainage area. (Expression is future growth term for expanding or newly designated MS4s.)

PROPOSED E. COLI TOTAL MAXIMUM DAILY LOAD (TMDL)
Watauga River Watershed (HUC 06010103)

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those waterbodies that are not attaining water quality standards. State water quality standards consist of designated uses for individual waterbodies, appropriate numeric and narrative water quality criteria protective of the designated uses, and an antidegradation statement. The TMDL process establishes the maximum allowable loadings of pollutants for a waterbody that will allow the waterbody to maintain water quality standards. The TMDL may then be used to develop controls for reducing pollution from both point and nonpoint sources in order to restore and maintain the quality of water resources (USEPA, 1991).

2.0 SCOPE OF DOCUMENT

This document presents details of TMDL development for waterbodies in the Watauga River watershed, identified on the Proposed Final 2014 303(d) list as not supporting designated uses due to E. coli. TMDL analyses were performed primarily on a 12-digit hydrologic unit area (HUC-12) basis. In some cases, where appropriate, TMDLs were developed for an impaired waterbody drainage area only.

Portions of the Watauga River Watershed are located in North Carolina. This TMDL only addresses the portion of the Watauga River Watershed located in Tennessee.

The E. coli TMDLs developed in this document supersede the pathogen TMDLs approved by EPA in 2006 for the Watauga River watershed.

3.0 WATERSHED DESCRIPTION

The Watauga River watershed (HUC 06010103) is located in Eastern Tennessee (Figure 1), primarily in Carter and Johnson counties. The Watauga River watershed lies within two Level III ecoregions (Blue Ridge Mountains, Ridge and Valley), which contain eight Level IV subecoregions, as shown in Figure 2 (USEPA, 1997):

- **Southern Igneous Ridges and Mountains (66d)** occur in Tennessee's northeastern Blue Ridge near the North Carolina border, primarily on Precambrian-age igneous and high-grade metamorphic rocks. The typical crystalline rock types include granite, gneiss, schist, and metavolcanics, covered by well-drained, acidic brown loamy soils. Elevations of this rough, dissected region range from 2000-6200 feet, with Roan Mountain reaching 6286 feet. Although there are a few small areas of pasture and apple orchards, the region is mostly forested; Appalachian oak and northern hardwood forests predominate.
- **The Southern Sedimentary Ridges (66e)** in Tennessee include some of the westernmost foothill areas of the Blue Ridges Mountains ecoregion, such as the Bean, Starr, Chilhowee, English, Stone, Bald, and Iron Mountain areas. Slopes are steep, and elevations are generally 1000-4500 feet. The rocks are primarily Cambrian-age

sedimentary (shale, sandstone, siltstone, quartzite, conglomerate), although some lower stream reachs occur on limestone. Soils are predominantly friable loams and fine sandy loams with variable amounts of sandstone rock fragments, and support mostly mixed oak and oak-pine forests.

- **Limestone Valleys and Coves (66f)** are small but distinct lowland areas of the Blue Ridge, with elevations mostly between 1500 and 2500 feet. About 450 million years ago, older Blue Ridge rocks to the east were forced up and over younger rocks to the west. In places, the Precambrian rocks have eroded through to Cambrian or Ordovician-age limestones, as seen especially in isolated, deep cove areas that are surrounded by steep mountains. The main areas of limestone include the Mountain City lowland area and Shady Valley in the north; and Wear Cove, Tuckaleechee Cove, and Cades Cove of the Great Smoky Mountains in the south. Hay and pasture, with some tobacco patches on small farms, are typical land uses.

- **The Southern Metasedimentary Mountains (66g)** are steep, dissected, biologically-diverse mountains that include Clingmans Dome (6643 feet), the highest point in Tennessee. The Precambrian-age metamorphic and sedimentary geologic materials are generally older and more metamorphosed than the Southern Sedimentary Ridges (66e) to the west and north. The Appalachian oak forests and, at higher elevations, the northern hardwoods forests include a variety of oaks and pines, as well as silverbell, hemlock, yellow poplar, basswood, buckeye, yellow birch, and beech. Spruce-fir forests, found generally above 5500 feet, have been affected greatly over the past twenty-five years by the balsam woolly aphid. The Copper Basin, in the southeast corner of Tennessee, was the site of copper mining and smelting from the 1850's to 1987, and once left more than fifty square miles of eroded earth.

- The **High Mountains (66i)** ecoregion includes three separate high-elevation areas in Tennessee above 4500 feet along the North Carolina line including portions of the Cherokee National Forest in Monroe County, Great Smoky Mountains National Park in Blount, Sevier and Cocke counties and Roan Mountain in Carter County. The region has a more sever, boreal-like climate than surrounding regions, with wind and ice affecting vegetation. It has frigid soils rather than mesic soils.

- The **Amphibolite Mountains (66k)** are a botanically diverse area with many rare species, including some relict and disjunct taxa from areas much further north. The amphibolite within these steeply sloping mountains is a metamorphosed black volcanic rock formed from lava that spilled on the floor of a shallow sea, mixing with layers of mud, sand and volcanic ash. In some areas, this rock weathers to produce shallow soils high in calcium and magnesium and less acidic than those found in most of Appalachia. There is only one extremely small area in Tennessee located in Johnson County on the North Carolina border near Nettle Knob.

- **The Southern Limestone/Dolomite Valleys and Low Rolling Hills (67f)** form a heterogeneous region composed predominantly of limestone and cherty dolomite. Landforms are mostly low rolling ridges and valleys, and the solids vary in their productivity. Landcover includes intensive agriculture, urban and industrial, or areas of thick forest. White oak forests, bottomland oak forests, and sycamore-ash-elm riparian forests are the common forest types, and grassland barrens intermixed with cedar-pine glades also occur here.

- **The Southern Shale Valleys (67g)** consist of lowlands, rolling valleys, and slopes and hilly areas that are dominated by shale materials. The northern areas are associated

> with Ordovician-age calcareous shale, and the well-drained soils are often slightly acid to neutral. In the south, the shale valleys are associated with Cambrian-age shales that contain some narrow bands of limestone, but the soils tend to be strongly acid. Small farms and rural residences subdivide the land. The steeper slopes are used for pasture or have reverted to brush and forested land, while small fields of hay, corn , tobacco, and garden crops are grown on the foot slopes and bottomland.

The Watauga River watershed (HUC 06010103) is located in Carter, Johnson, Sullivan, Unicoi, and Washington Counties, Tennessee. The Watauga River watershed has approximately 1,061 miles of streams in Tennessee (based on the EPA/Tennessee Department of Environment and Conservation (TDEC) Assessment Database (ADB)) and has a drainage area of approximately 871 square miles (mi^2), 663 of which are in Tennessee. Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from around 2006. Although changes in the land use of the Watauga River watershed have occurred since 2006 as a result of rapid development, this is the most current land use data available. Land use for the Watauga River watershed is summarized in Table 1 and shown in Figure 3. Predominant land use in the Tennessee portion of the Watauga River watershed is agriculture and forest (37% each). Urban areas represent approximately 26% of the total drainage area of the watershed. Details of land use distribution of impaired subwatersheds in the Watauga River watershed are presented in Appendix A.

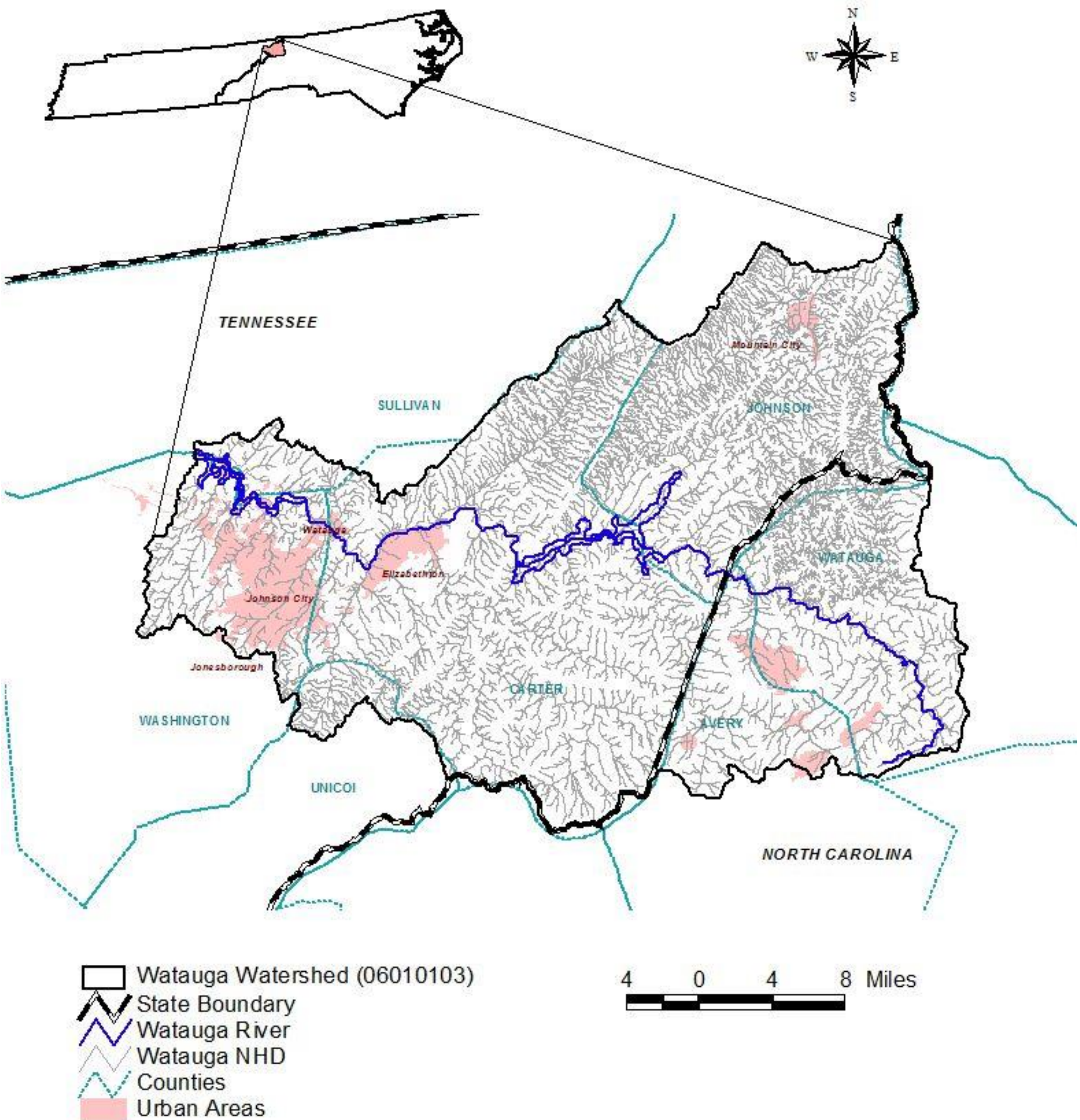

Figure 1. Location of the Watauga River Watershed

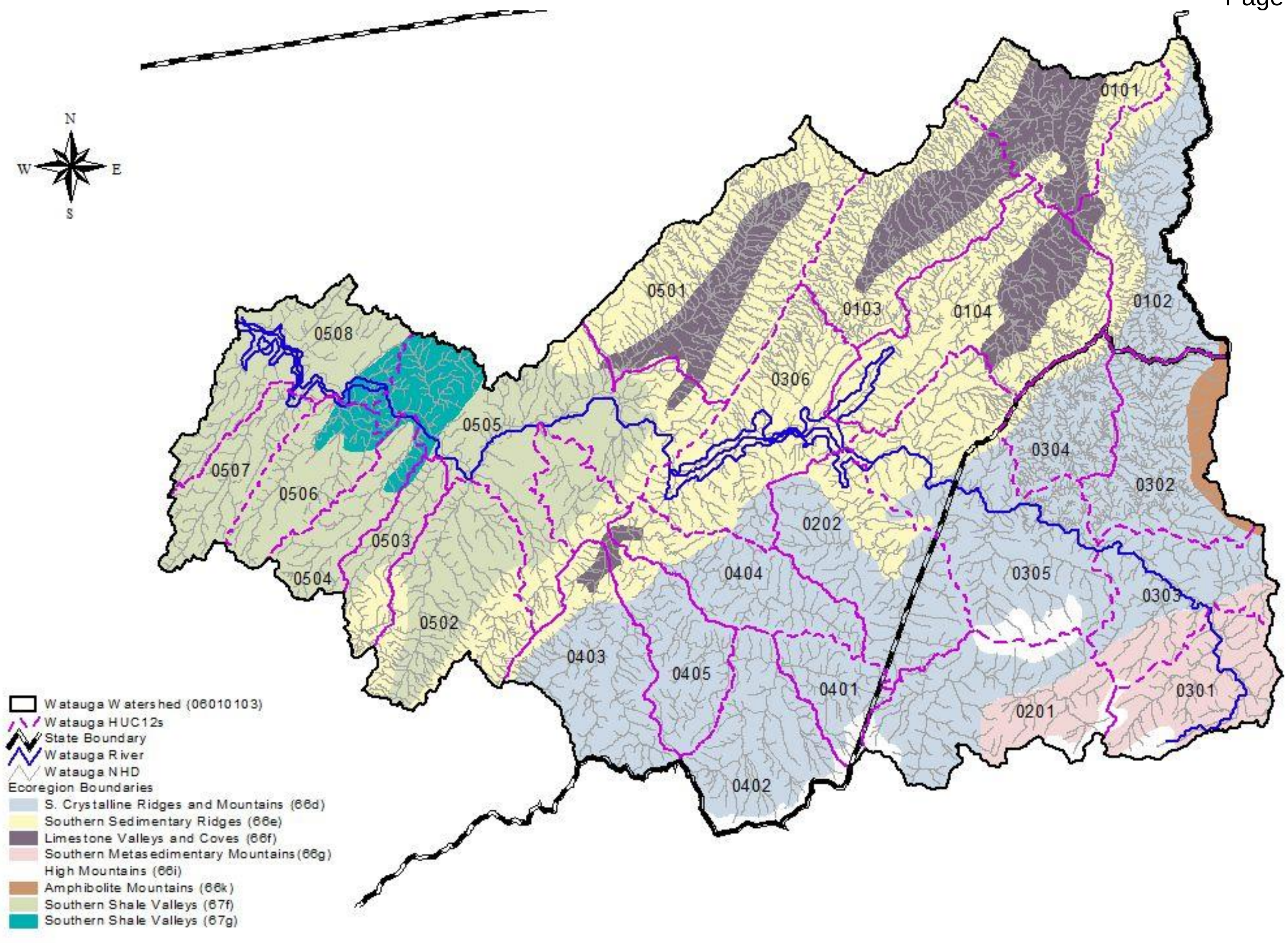

Figure 2. Level IV Ecoregions in the Watauga River Watershed

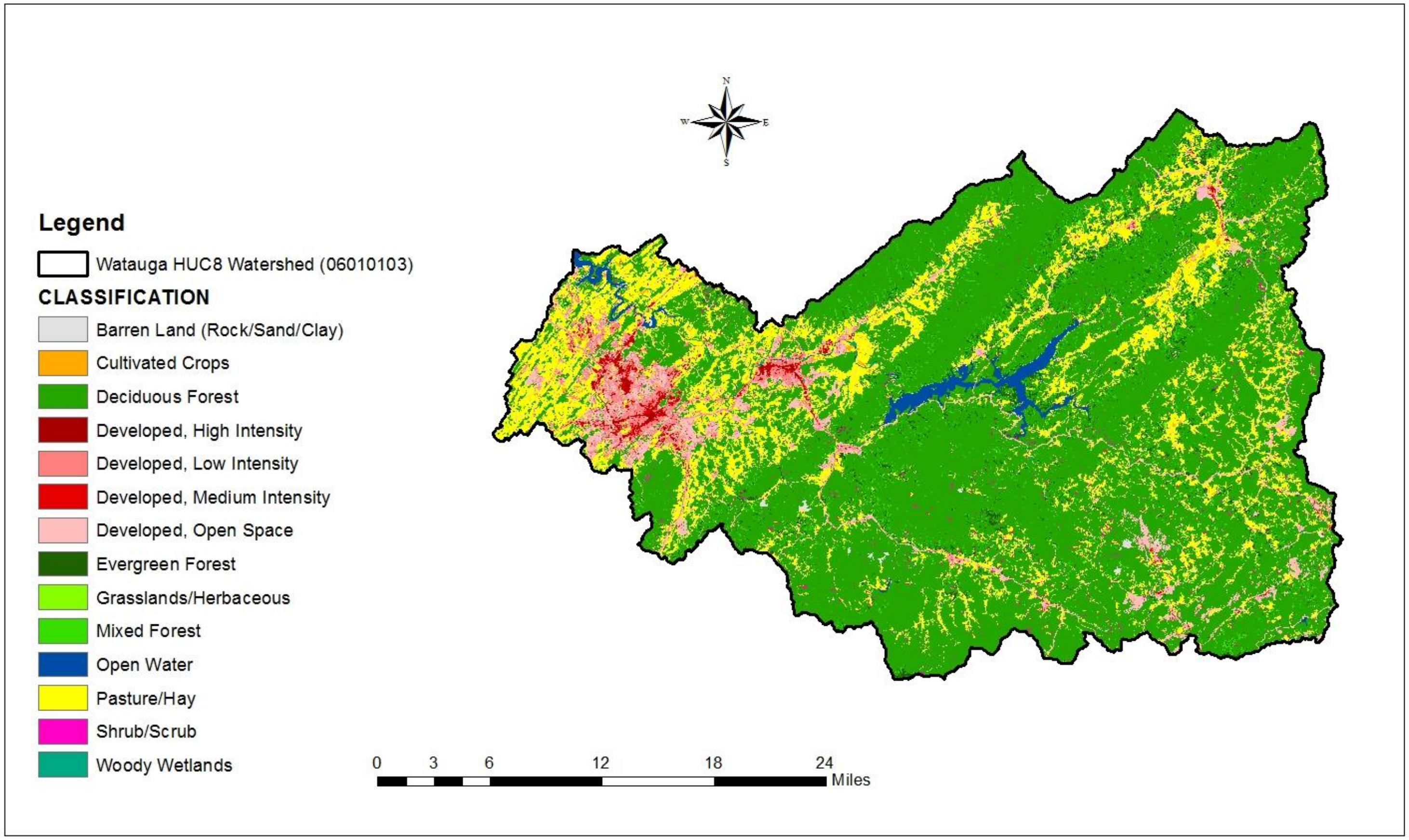

Figure 3. Land Use Characteristics of the Watauga River Watershed

Table 1. MRLC Land Use Distribution – Watauga River Watershed

Land use	Tennessee & North Carolina		Tennessee Portion Only	
	[acres]	[%]	[acres]	[%]
Unclassified	0	0.00%	0	0.00%
Open Water	19,298	3.46%	18,089	4.26
Developed Open Spaces	99,131	17.78%	68,749	16.20
Low Intensity Residential	33,777	6.06%	29,980	7.07
Medium Intensity Residential	9,579	1.72%	8,437	1.99
High Intensity Residential	3,724	0.67%	3,491	0.82
Bare Rock/Sand/Clay	3,485	0.63%	2,212	0.52
Deciduous Forest	91,732	16.46%	63,653	15.00
Evergreen Forest	34,148	6.13%	27,236	6.42
Mixed Forest	30,893	5.54%	24,111	5.68
Shrub/Scrub	10,539	1.89%	6,434	1.52
Grassland/Herbaceous	15,353	2.75%	10,640	2.51
Pasture/Hay	201,801	36.20%	157,892	37.21
Cultivated Crops	2,869	0.51%	2,516	0.59
Woody Wetlands	1,111	0.20%	882	0.21
Emergent Herbaceous Wetlands	0	0.00%	0	0.00%
Total	557,440	100.00%	424,320	100.00%

Note: A spreadsheet was used for this calculation and values are approximate due to rounding.

4.0 PROBLEM DEFINITION

The State of Tennessee's Proposed Final 2014 303(d) list (TDEC, 2014), http://www.tn.gov/environment/water/docs/wpc/2014-proposed-final-303d-list.pdf, was submitted to EPA, Region IV, in September 2014. This list identified a number of waterbodies in the Watauga River watershed as not fully supporting designated use classifications due, in part, to E. coli (see Table 2 & Figure 4). The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Portions of Buffalo Creek, Davis Branch, Gap Creek, and Roan Creek are designated as trout streams or naturally reproducing trout streams. Roan Creek (except for mile 16.7 to 17.7 in Mountain City) is also designated for domestic water supply and industrial water supply.

5.0 WATER QUALITY CRITERIA & TMDL TARGET

As previously stated, the designated use classifications for the Watauga River waterbodies include fish & aquatic life, recreation, irrigation, livestock watering & wildlife. Of the use classifications with numeric criteria for E. coli, the recreation use classification is the most stringent and will be used to establish target levels for TMDL development. The coliform water quality criteria, for protection of the recreation use classification, is established by *State of Tennessee Water Quality Standards, Chapter 0400-40-03, General Water Quality Criteria, 2013 Version* (TDEC, 2013).

Roan Creek (except for mile 16.7 to 17.7 in Mountain City) is classified as an Exceptional Tennessee Water. The portions of Gap Creek and Davis Branch that flow through the Cherokee National Forest are classified as Exceptional Tennessee Waters. As of December 1, 2014, none of the other impaired waterbodies in the Watauga River watershed have been classified as lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters.

For further information concerning Tennessee's general water quality criteria and Tennessee's Antidegradation Statement, including the definition of Exceptional Tennessee Water, see:

http://www.tn.gov/sos/rules/0400/0400-40/0400-40-03.20131216.pdf

The geometric mean standard for the E. coli group of 126 colony forming units per 100 ml (CFU/100 ml) and the sample maximum of 487 CFU/100 ml have been selected as the appropriate numerical targets for TMDL development for Exceptional Tennessee Waters. The geometric mean standard for the E. coli group of 126 colony forming units per 100 ml (CFU/100 ml) and the sample maximum of 941 CFU/100 ml have been selected as the appropriate numerical targets for TMDL development for the other impaired waterbodies.

Table 2. Proposed Final 2014 303(d) List for E. coli Impaired Waterbodies – Watauga River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN06010103001T - 0100	Darr Creek	3.85	Loss of biological integrity due to siltation Alteration in stream-side or littoral vegetative cover Escherichia coli	Pasture Grazing
TN06010103006 - 0100	Carroll Creek	4.3	Nitrate+Nitrite Loss of biological integrity due to siltation Alteration in stream-side or littoral vegetative cover Escherichia coli	Discharges from MS4 Area Pasture Grazing
TN06010103006 – 1000	Boones Creek	19.31	Nitrate+Nitrite Loss of biological integrity due to siltation Alteration in stream-side or littoral vegetative cover Escherichia coli	Discharges from MS4 Area Pasture Grazing Land Development
TN06010103008 - 0400	Davis Branch	5.9	Flow Alteration Alteration in stream-side or littoral vegetative cover Escherichia coli	Discharges from MS4 Area Upstream Impoundment Pasture Grazing
TN06010103008 - 0800	Gap Creek	15.93	Nitrate+Nitrite Loss of biological integrity due to siltation Alteration in stream-side or littoral vegetative cover Escherichia coli	Discharges from MS4 Area Streambank Modification Septic Tanks Pasture Grazing
TN06010103009 - 1000	Brush Creek	20.3	Nitrate+Nitrite Loss of biological integrity due to siltation Other Anthropogenic Habitat Alterations Escherichia coli	Discharges from MS4 Area
TN06010103011 - 0100	Powder Branch	6.2	Nitrate+Nitrite Loss of biological integrity due to siltation Alteration in stream-side or littoral vegetative cover Escherichia coli	Pasture Grazing

Table 2 (con't). Proposed Final 2014 303(d) List for E. coli Impaired Waterbodies – Watauga River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN06010103011 - 0200	Toll Branch	6.5	Escherichia coli	Pasture Grazing
TN06010103011 - 1000	Buffalo Creek (from Watauga River to Unicoi County line)	6.08	Escherichia coli	Pasture Grazing
TN06010103020T - 0200	Sink Branch	3.14	Nitrate+Nitrite Alteration in stream-side or littoral vegetative cover Escherichia coli	Pasture Grazing
TN06010103034 - 0300	Town Creek	3.0	Nitrate+Nitrite Alteration in stream-side or littoral vegetative cover Escherichia coli	Land Development Urbanized High Density Area Pasture Grazing Collection System Failure Municipal Point Source
TN06010103034 - 2000	Roan Creek (from Mill Creek to Lumpkin Branch)	6.0	Nitrate+Nitrite Loss of biological integrity due to siltation Escherichia coli	Municipal Point Source Pasture Grazing
TN06010103046 - 1000	Sinking Creek	10.0	Escherichia coli	Discharges from MS4 Area Pasture Grazing
TN06010103061 – 1000	Reedy Creek	10.7	Escherichia coli	Discharges from MS4 Area Pasture Grazing
TN06010103635 – 0100	Cash Hollow Creek	3.48	Alteration in stream-side or littoral vegetative cover Escherichia coli	Discharges from MS4 Area
TN06010103635 – 0200	Cobb Creek	4.5	Loss of biological integrity due to siltation Alteration in stream-side or littoral vegetative cover Escherichia coli	Discharges from MS4 Area
TN06010103635 – 1000	Knob Creek	12.3	Nitrate+Nitrite Loss of biological integrity due to siltation Alteration in stream-side or littoral vegetative cover Escherichia coli	Discharges from MS4 Area Pasture Grazing

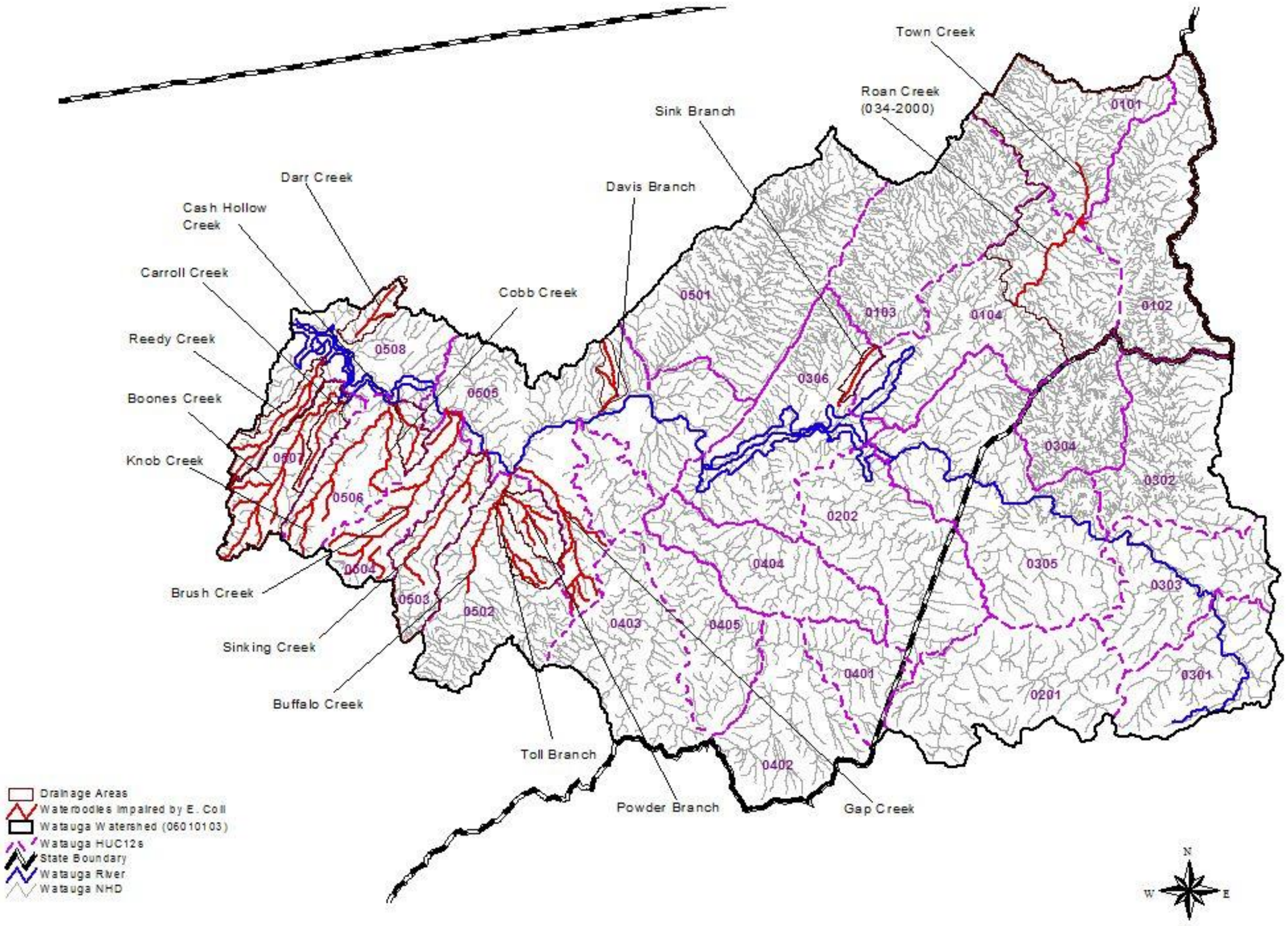

Figure 4. Waterbodies Impaired by E. Coli (as Documented on the Proposed Final 2014 303(d) List)

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM TARGET

The following water quality monitoring stations provided data for waterbodies identified as impaired for E. coli in the Watauga River watershed:

- HUC-12 06010103_0101:
  - TOWN000.3JO – Town Creek, d/s Mountain City WWTP, off Lumpkin Branch Rd.
  - TOWN000.9JO – Town Creek at Dotson Rd., at bridge at TDOT
- HUC-12 06010103_0102:
  - *ROAN018.2JO – Roan Creek at bridge at church, u/s Mountain City WWTP*
- HUC-12 06010103_0104:
  - *ROAN011.8JO – Roan Creek at u/s side of bridge, Big Dry Run @ confluence Mill Creek, first bridge*
  - *ROAN016.6JO – Roan Creek off SR 167 at Maymead Farm*
- HUC-12 06010103_0306:
  - SINK000.7JO – Sink Branch at Sink Valley Rd. (2.0 mi from C. Matherly Rd.)
- HUC-12 06010103_0502:
  - BUFFA000.2CT – Buffalo Creek at baseball field off US 321
  - BUFFA005.5CT – Buffalo Creek at Peoples Farm Rd., near One Stop Market
  - BUFFA006.3CT – Buffalo Creek at Unicoi Dr.
  - POWDE000.4CT – Powder Branch at Powder Branch Rd. (SR 2558), off Milligan Hwy (SR 359), E of Happy Valley HS
  - TOLL000.3CT – Toll Branch at 159 Warrior Ln., off Milligan Hwy (SR 359), W of Happy Valley HS
  - TOLL001.5CT – Toll Branch at intersection of Toll Branch Rd. and Toll Branch Spur, 0.7 mi SE of Milligan College
  - TOLL002.5CT – Toll Branch at #338 Toll Branch Rd. spring head
- HUC-12 06010103_0503:
  - SINKI000.6CT – Sinking Creek at new pump station, 243 Sinking Creek Rd.
- HUC-12 06010103_0504:
  - BRUSH000.7WN – Brush Creek at St. Johns Mill on Watauga Rd.
  - BRUSH006.1WN – Brush Creek at Watauga Ave., next to Church Brothers

- HUC-12 06010103_0505:
    - DAVIS000.9CT – Davis Branch, d/s airport, across SR91, beside armory
    - GAP000.1CT – Gap Creek in Watauga Point, between Hwy 321 and W.G. Street
    - GAP000.4CT – Gap Creek at SR 67 – Old Eliz Hwy, NE of Grindstaff
- HUC-12 06010103_0506:
    - KNOB001.0WN – Knob Creek, u/s Old Knob Creek WWTP, off Austins Springs Rd.
    - KNOB003.7WN – Knob Creek, d/s Old Knob Creek WWTP
    - KNOB005.8WN – Knob Creek at intersection of Knob Creek Rd and Fairridge Rd.
    - KNOB007.1WN – Knob Creek at Moss Creek Dr.
    - COBB000.1WN – Cobb Creek off Austins Springs Rd., u/s Old Knob Creek WWTP
    - COBB001.0WN – Cobb Creek at 293 Austin Springs Rd. (Austin Springs Terrace Apts.)
    - CASH_G0.3WN – Cash Hollow Creek near Austin Springs Rd.
    - CASH_G2.7WN – Cash Hollow Creek at Cash Hollow Road bridge
- HUC-12 06010103_0507:
    - BOONE000.7WN – Boones Creek at Lester Rd.
    - BOONE001.7WN – Boones Creek at off Pickens Br Rd.
    - BOONE003.7WN – Boones Creek at Christian Church Rd.
    - BOONE007.6WN – Boones Creek at Bugaboo Springs Rd.
    - CARRO000.5WN – Carroll Creek at Cedar Point Rd. (confluence w/ Boones Creek)
    - CARRO000.7WN – Carroll Creek at Carroll Creek Rd (confluence w/ Boones Creek)
- HUC-12 06010103_0508:
    - DARR001.2SU – Darr Creek at Pinet Flats Warren Dr., N of Pickets bridge
    - REEDY001.8WN – Reedy Creek at White Street, off Boring Chapel Rd.

The locations of these monitoring stations are shown in Figures 5 and 6. The water quality monitoring results for these stations are tabulated in Appendix B. Examination of the data shows exceedances of the 941 CFU/100 mL maximum E. coli standard at virtually all monitoring stations on the impaired waterbodies. Water quality monitoring results for those stations are summarized in Table 3.

Whenever a minimum of 5 samples was collected at a given monitoring station over a period of not more than 30 consecutive days, the geometric mean was calculated. There were sufficient data to conduct geometric mean analyses at many of the monitoring stations.

Several of the water quality monitoring stations (Table 3 and Appendix B) have at least one E. coli sample value reported as >2420. For the purpose of calculating summary data statistics, TMDLs, Waste Load Allocations (WLAs), and Load Allocations (LAs), these data values are treated as (equal to) 2420. Therefore, the calculated results are considered to be estimates. Future E. coli sample analyses at these sites should follow established protocol (see Section 9.4.).

Table 3. Summary of TDEC Water Quality Monitoring Data

Monitoring Station	Date Range [a]	E. coli (Max. WQ Target = 941 cfu/100 mL) (Geomean WQ Target = 126 cfu/100 mL)*					
		# of Data Points	Min. [CFU/100mL]	Avg. [CFU/100mL]	Max. [CFU/100mL]	Geomean** [CFU/100mL]	No. Exceedances WQ Max. Target
BOONE000.7WN	2006 – 2012	31	82	2,878	46,110	1,048	19
	2011 – 2012	12	201	5,421	46,110	1,048	9
BOONE001.7WN	2006 – 2012	24	98	2,136	32,550	844	10
	2011 – 2012	12	166	3,622	32,550	844	6
BOONE003.7WN	2006 – 2012	23	194	5,026	38,730	1,944	19
	2011 – 2012	12	727	5,657	38,730	1,944	11
BOONE007.6WN	2006 – 2012	30	649	6,583	64,880	2,908	31
	2011 – 2012	12	649	3,552	12,110	2,908	11
BRUSH000.7WN	2006 – 2012	27	43	752	5,370	357	4
	2011 – 2012	12	107	733	5,370	357	1
BRUSH006.1WN	2012	6	23	56	96	49	0
BUFFA000.2CT	2006 – 2012	22	66	440	2,920	323	1
	2011 – 2012	12	66	483	2,920	321	1
CARRO000.5WN	2011 – 2012	12	49	559	2,420	237	1
CASH_G0.3WN	1999 – 2012	23	114	1,214	9,330	1,365	7
	2011 – 2012	12	114	1,759	9,330	1,365	5
CASH_G2.7WN	1999 – 2012	23	38	346	1,300	312	1
	2011 – 2012	12	66	363	770	312	0
COBB000.1WN	2006 – 2012	19	18	396	1,300	504	2
	2011 – 2012	12	65	448	1,300	504	2
COBB001.0WN	2011 – 2012	12	71	504	2,420	264	2

Table 3 (cont'd). Summary of TDEC Water Quality Monitoring Data

Monitoring Station	Date Range [a]	E. coli (Max. WQ Target = 941 cfu/100 mL) (Geomean WQ Target = 126 cfu/100 mL)*					
		# of Data Points	Min. [CFU/100mL]	Avg. [CFU/100mL]	Max. [CFU/100mL]	Geomean** [CFU/100mL]	No. Exceedances WQ Max. Target
DARR001.2SU	2011 – 2012	12	138	1,376	6,850	853	5
DAVIS000.9CT	2001 – 2012	32	5	522	2,420	365	6
	2011 – 2012	13	17	517	2,420	365	2
GAP000.1CT	2007 – 2012	18	99	1,386	5,460	2,324	8
	2011 – 2012	12	201	1,752	5,460	2,324	7
KNOB001.0WN	2006 – 2012	29	24	725	4,140	608	7
	2011 – 2012	11	133	1,087	4,140	608	4
KNOB003.7WN	2006 – 2012	24	74	1,728	20,640	579	7
	2011 – 2012	12	74	2,470	20,640	579	4
KNOB005.8WN	2006 – 2012	30	86	3,026	36,540	2,528	14
	2011 – 2012	12	86	941	3,270	972	3
KNOB007.1WN	2006 – 2012	24	236	2,537	17,220	2,195	19
	2011 – 2012	12	236	1,758	4,410	2,195	9
POWDE000.4CT	2011 – 2012	12	50	1,431	7,940	872	3
REEDY001.8WN	2006 – 2012	34	80	3,423	68,670	2,007	20
	2011 – 2012	12	119	647	1,986	368	2
ROAN011.8JO	*2001 – 2012*	*28*	*1*	*223*	*1,220*	*169*	*3*
	2011 – 2012	*12*	*1*	*127*	*365*	*169*	*0*
ROAN016.6JO	*2001 – 2012*	*30*	*2*	*1,445*	*15,530*	*368*	*12*
	2011 – 2012	*12*	*3*	*2,212*	*15,530*	*368*	*3*
ROAN018.2JO	*2001 – 2012*	*26*	*1*	*188*	*1,100*	*24*	*5*
	2011 – 2012	*12*	*1*	*28*	*119*	*24*	*0*

Table 3 (cont'd). Summary of TDEC Water Quality Monitoring Data

Monitoring Station	Date Range [a]	E. coli (Max. WQ Target = 941 cfu/100 mL) (Geomean WQ Target = 126 cfu/100 mL)*					
		# of Data Points	Min. [CFU/100mL]	Avg. [CFU/100mL]	Max. [CFU/100mL]	Geomean** [CFU/100mL]	No. Exceedances WQ Max. Target
SINK000.7JO	2006 – 2012	31	1	4,292	30,760	6,135	17
	2011 – 2012	12	27	4,921	23,820	6,135	7
SINKI000.6CT	1999 – 2012	23	44	580	4,320	257	4
	2011 – 2012	12	71	648	4,320	257	2
TOLL000.3CT	2011 – 2012	12	187	50,986	>241,960	45,776	9
TOLL001.5CT	2012	4	201	253	299	Ngd	0
TOLL002.5CT	2012 – 2013	4	1	128	435	Ngd	0
TOWN000.3JO	2006 – 2012	16	1	172	816	Ngd	0
	2011 – 2012	12	1	224	816	Ngd	0
TOWN000.9JO	2006 – 2012	31	1	120	1,553	235	2
	2011 – 2012	12	1	295	1,553	235	1

* Maximum water quality target is 487 CFU/100 mL for lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters waterbodies and 941 CFU/100 mL for other waterbodies. Waterbodies utilizing the 487 CFU/100 mL target are italicized.
** If multiple geomean sampling periods are available, the maximum calculated geomean value is recorded.
[a] When two date ranges are presented, the first is period of record and the second is the most recent five year period.
Ngd = no geomean data

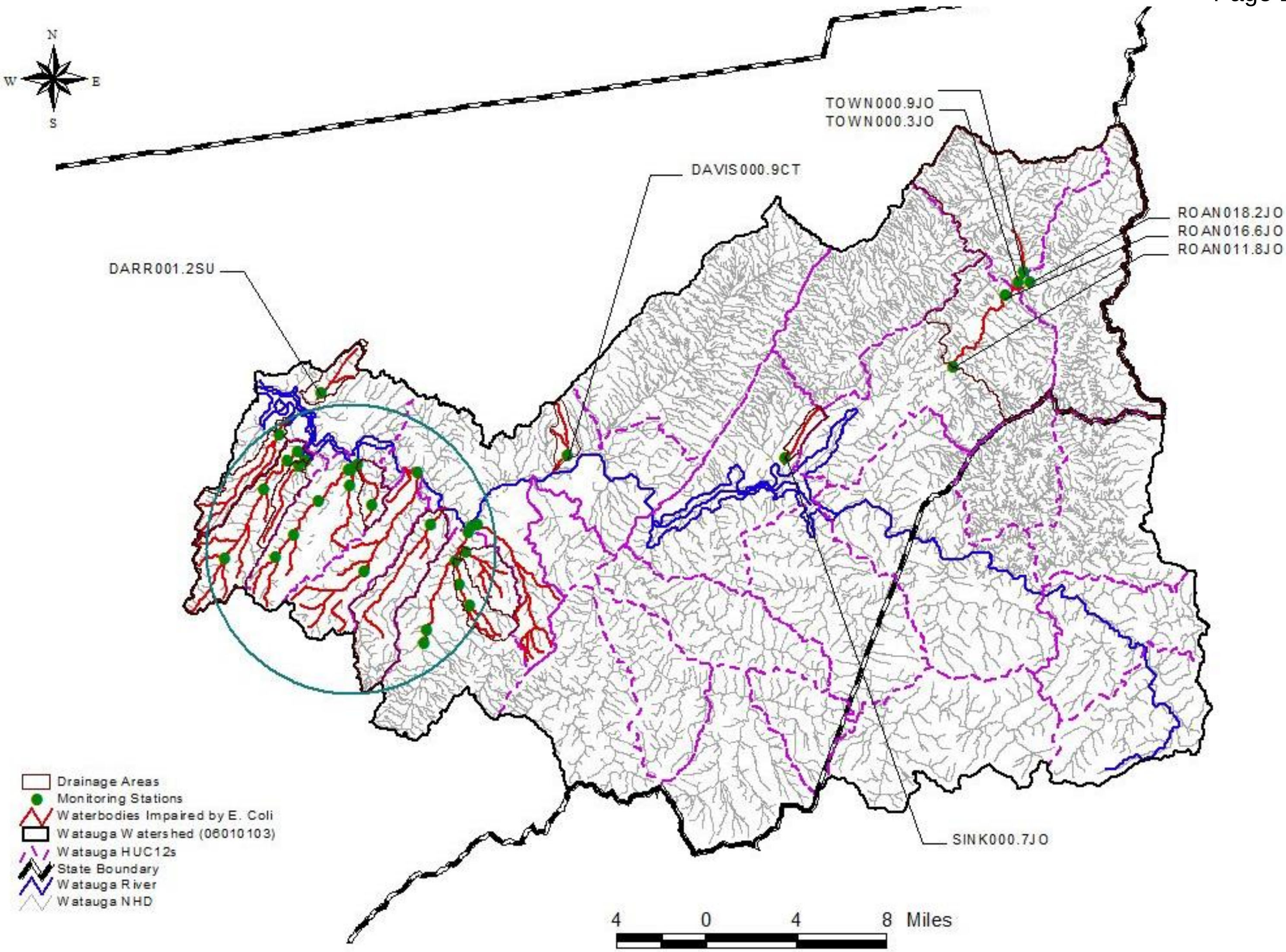

Figure 5. Water Quality Monitoring Stations in the Watauga River Watershed

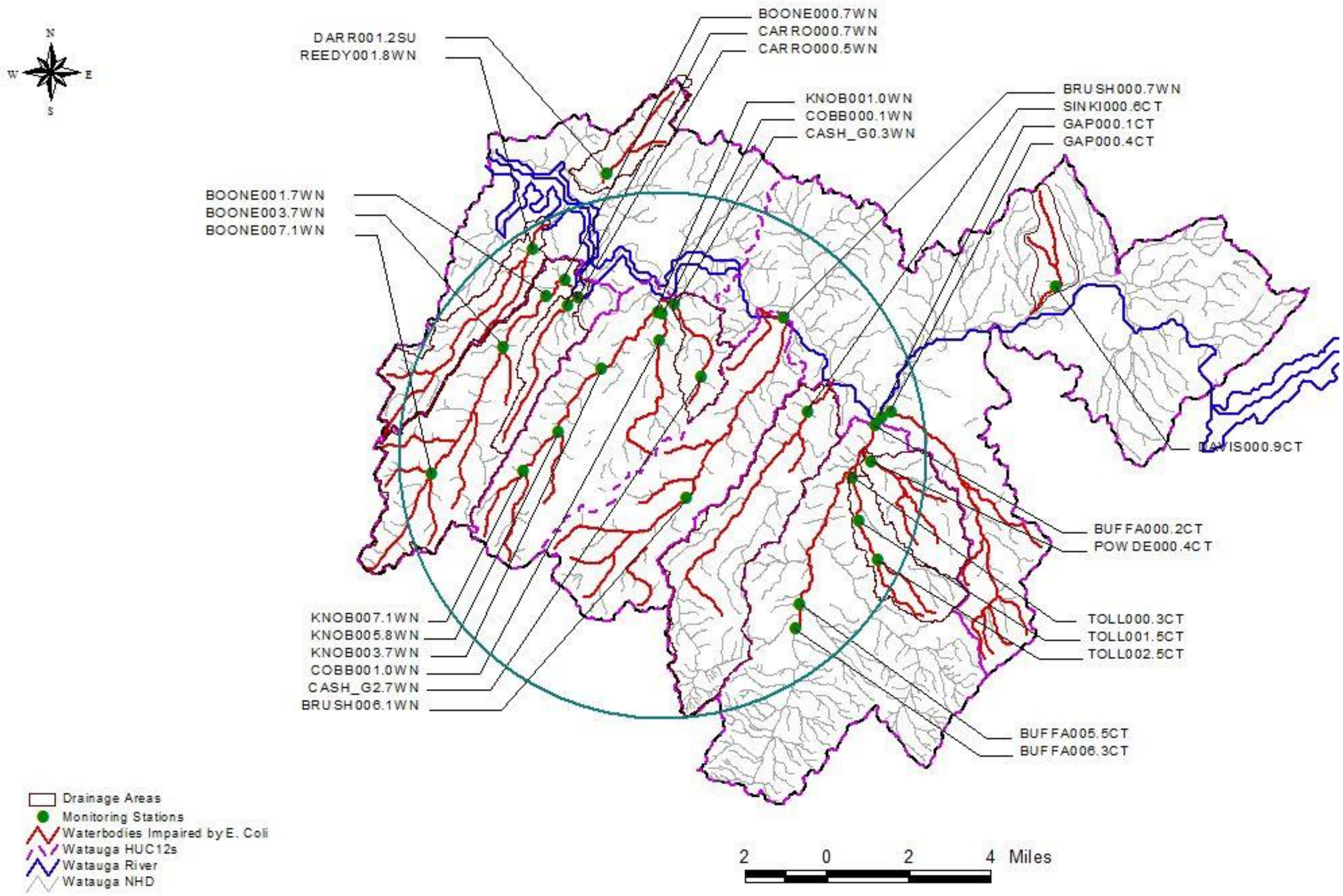

Figure 6. Water Quality Monitoring Stations in the HUC10 06010103-05

7.0 SOURCE ASSESSMENT

An important part of TMDL analysis is the identification of individual sources, or source categories of pollutants in the watershed that affect pathogen loading and the amount of loading contributed by each of these sources.

Under the Clean Water Act, sources are classified as either point or nonpoint sources. Under 40 CFR §122.2, (http://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol22/pdf/CFR-2011-title40-vol22-sec122-2.pdf), a point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program (http://cfpub1.epa.gov/npdes/index.cfm) regulates point source discharges. Point sources can be described by three broad categories: 1) NPDES regulated municipal (http://cfpub1.epa.gov/npdes/home.cfm?program_id=13) and industrial (http://cfpub1.epa.gov/npdes/home.cfm?program_id=14) wastewater treatment facilities (WWTPs); 2) NPDES regulated industrial and municipal storm water discharges (http://cfpub1.epa.gov/npdes/home.cfm?program_id=6); and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs) (http://cfpub1.epa.gov/npdes/home.cfm?program_id=7). A TMDL must provide Waste Load Allocations (WLAs) for all NPDES regulated point sources. Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a Load Allocation (LA) for these sources.

7.1 Point Sources

7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain coliform bacteria. There are 13 facilities in the Tennessee portion of the Watauga River watershed that have NPDES permits authorizing the discharge of treated sanitary wastewater. Four of these facilities are located in impaired subwatersheds or drainage areas, but only one facility discharges to an impaired waterbody (Figure 7 and Table 4). All of the facilities are sewage treatment plants (STPs) serving municipalities and are major facilities with design capacities equal to or greater than 1.0 million gallons per day (MGD). The permit limits for discharges from these WWTPs are in accordance with the coliform criteria specified in Tennessee Water Quality Standards for the protection of the recreation use classification.

Non-permitted point sources of (potential) E. coli contamination of surface waters associated with STP collection systems include leaking collection systems (LCSs) and sanitary sewer overflows (SSOs).

> *Note: As stated in Section 5.0, the current coliform criteria are expressed in terms of E. coli concentration, whereas previous criteria were expressed in terms of fecal coliform and E. coli concentration. Due to differences in permit issuance dates, some permits still have fecal coliform limits instead of E. coli. As permits are reissued, limits for fecal coliform should be replaced by E. coli limits.*

Table 4. WWTPs with NPDES Permits to Discharge Sanitary Wastewater to Impaired Subwatersheds or Drainage Areas

NPDES Permit No.	Facility	Design Flow [MGD]	Receiving Stream
TN0024945	Mountain City STP	1.2	Town Creek @mile 0.4

7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of E. coli. Discharges from MS4s occur in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. Phase I of the EPA storm water program (http://water.epa.gov/polwaste/npdes/stormwater/Municipal-Separate-Storm-Sewer-System-MS4-Main-Page.cfm) requires large and medium MS4s to obtain NPDES storm water permits. Large and medium MS4s are those located in incorporated places or counties serving populations greater than 100,000 people. There are no Phase I MS4s located in the Watauga River watershed.

As of March 2003, regulated small MS4s in Tennessee must also obtain NPDES permits in accordance with the Phase II storm water program (http://water.epa.gov/polwaste/npdes/stormwater/Municipal-Separate-Storm-Sewer-System-MS4-Main-Page.cfm. A small MS4 is designated as *regulated* if: a) it is located within the boundaries of a defined urbanized area that has a residential population of at least 50,000 people and an overall population density of 1,000 people per square mile; b) it is located outside of an urbanized area but within a jurisdiction with a population of at least 10,000 people, a population density of 1,000 people per square mile, and has the potential to cause an adverse impact on water quality; or c) it is located outside of an urbanized area but contributes substantially to the pollutant loadings of a physically interconnected MS4 regulated by the NPDES storm water program. Most regulated small MS4s in Tennessee obtain coverage under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* http://www.tn.gov/environment/water/docs/wpc/tns000000_MS4_phase_ii_2010.pdf (TDEC, 2010). The City of Elizabethton and the City of Johnson City, and Carter County, Sullivan County, and Washington County are covered under Phase II of the NPDES Storm Water Program.

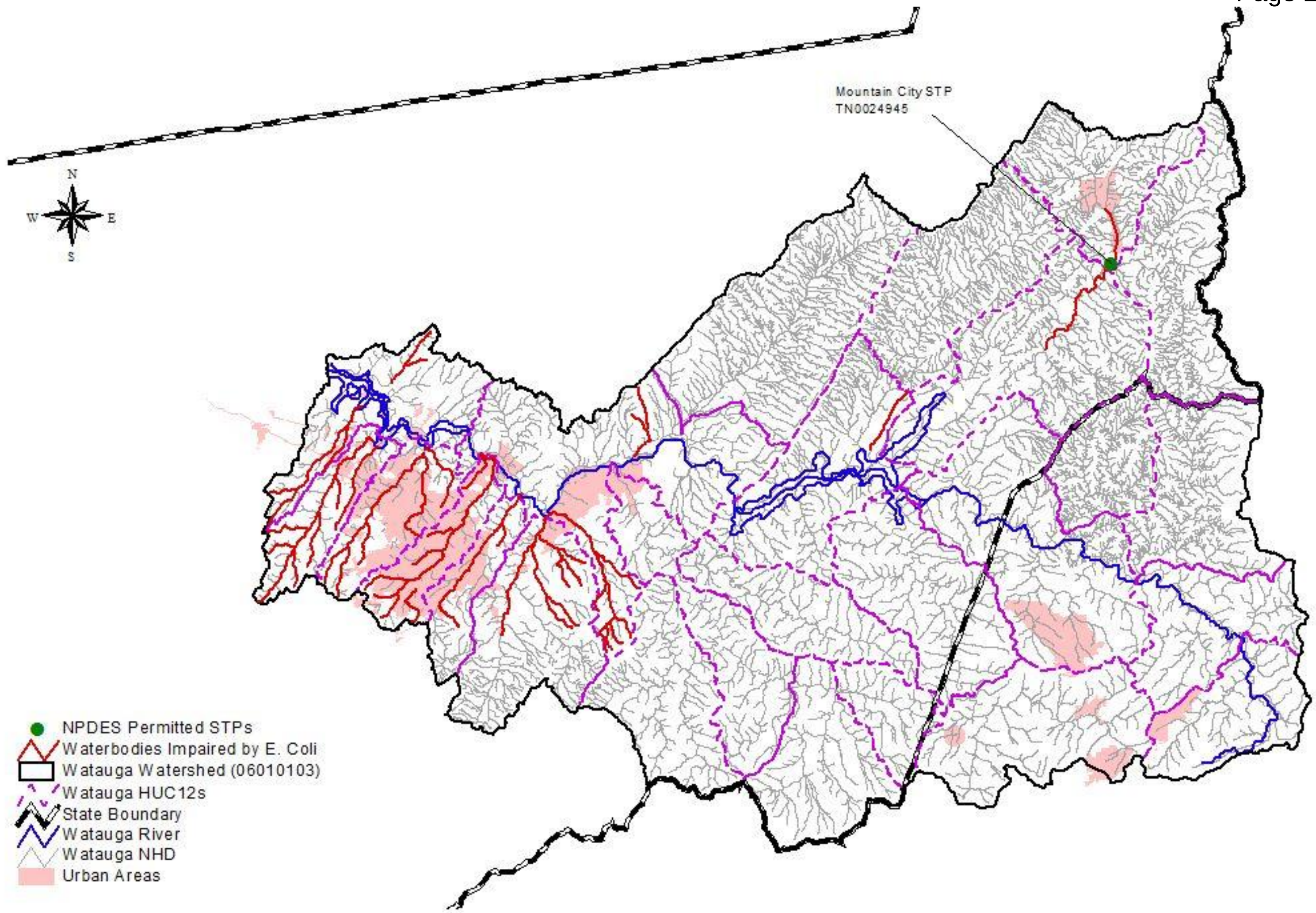

Figure 7. WWTPs with NPDES Permits to Discharge Sanitary Wastewater to Impaired Subwatersheds and Drainage Areas of the Watauga River Watershed

The Tennessee Department of Transportation (TDOT) has been issued an individual MS4 permit (TNS077585) that authorizes discharges of stormwater runoff from State roads and interstate highway right-of-ways that TDOT owns or maintains, discharges of stormwater runoff from TDOT owned or operated facilities, and certain specified non-storm water discharges. This permit covers all eligible TDOT discharges statewide, including those located outside of urbanized areas. The TDOT MS4 will not be considered a potential source because: (1) the area covered by the permit is less than 0.5% of the total drainage area of the watershed; (2) sampling of stormwater runoff from state highways indicates negligible contribution of E. coli; and (3) an extensive study conducted by California Dept. of Transportation (CalTrans) concluded that highway facilities, including maintenance stations, do not appear to be significant sources of pathogens in urban drainage. For information regarding storm water permitting in Tennessee, see the TDEC website:

http://www.tn.gov/environment/water/water-quality_storm-water.shtml

7.1.3 NPDES Concentrated Animal Feeding Operations (CAFOs)

Animal feeding operations (AFOs) are agricultural enterprises where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland (USEPA, 2002a). Concentrated Animal Feeding Operations (CAFOs) are AFOs that meet certain criteria with respect to animal type, number of animals, and type of manure management system. CAFOs are considered to be potential point sources of pathogen loading and are required to obtain a State Operating Permit (SOP) or an NPDES permit. Most CAFOs in Tennessee qualify as Class II and obtain coverage under SOPC00000 or SOPCD0000, *General State Operating Permit for Concentrated Animal Feeding Operations* (https://www.tn.gov/environment/permits/cafo.shtml, while larger, Class I CAFOs are required to obtain an individual NPDES permit.

As of November 1, 2014, there are no Class I or II CAFOs with coverage or pending coverage under NPDES permits or the new general SOP permits.

7.2 Nonpoint Sources

Nonpoint sources of coliform bacteria are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources generally, but not always, involve accumulation of coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of E. coli loading are primarily associated with agricultural and urban land uses. The majority of waterbodies identified on the Proposed Final 2014 303(d) List as impaired due to E. coli are attributed to nonpoint agricultural or urban sources.

7.2.1 Wildlife

Wildlife deposit coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile.

7.2.2 Agricultural Animals

Agricultural activities can be a significant source of coliform bacteria loading to surface waters. The activities of greatest concern are typically those associated with livestock operations:

- Agricultural livestock grazing in pastures deposit manure containing coliform bacteria onto land surfaces. This material accumulates during periods of dry weather and is available for washoff and transport to surface waters during storm events. The number of animals in pasture and the time spent grazing are important factors in determining the loading contribution.

- Processed agricultural manure from confined feeding operations is often applied to land surfaces and can provide a significant source of coliform bacteria loading. Guidance for issues relating to manure application is available through the University of Tennessee Agricultural Extension Service and the Natural Resources Conservation Service (NRCS).

- Agricultural livestock and other unconfined animals often have direct access to waterbodies and can provide a concentrated source of coliform bacteria loading directly to a stream.

Data sources related to livestock operations include the 2012 Census of Agriculture http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/Tennessee/. Livestock data for counties located within the Watauga River watershed are summarized in Table 5. Note that, due to confidentiality issues, any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2014).

7.2.3 Failing Septic Systems

Some of the coliform loading in the Watauga River watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. Estimates of population utilizing septic systems for counties in the Watauga River watershed were derived from 2010 county census data and the percent of population on septic systems in 1990 (the last year the data are available), and are summarized in Table 6. In Tennessee, it is estimated that there are approximately 2.47 people per household on septic systems, some of which can be reasonably assumed to be failing. As with livestock in streams, failing septic systems have the potential to provide a concentrated source of coliform bacteria directly to waterbodies.

7.2.4 Urban Development

Nonpoint source loading of coliform bacteria from urban land use areas is attributable to multiple sources. These include: stormwater runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Impervious surfaces in urban areas allow runoff to be conveyed to streams quickly, without interaction with soils and groundwater. Urban land use area in impaired subwatersheds in the Watauga River watershed ranges from 4.0% to 74.1%. Land use for the Watauga River drainage areas and HUC-12 subwatersheds is summarized in Figures 8-13, and tabulated in Appendix A.

Table 5. Livestock Distribution in the Watauga River Watershed

County	Livestock Population (2012 Census of Agriculture)							
	Beef Cow	Milk Cow	Poultry		Hogs	Sheep	Goats	Horse
			Layers	Broilers				
Carter	4,524	185	483	58	63	212	508	622
Johnson	(D)	(D)	1,356	102	11	123	563	502
Sullivan	10,919	422	3,613	188	(D)	2,891	837	1,572
Unicoi	(D)	(D)	112	62	(D)	44	74	52
Washington	17,681	1,361	2,030	(D)	257	1,537	1,188	1,675

* In keeping with the provisions of Title 7 of the United States Code, no data are published in the 2012 Census of Agriculture that would disclose information about the operations of an individual farm or ranch. Any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2014).

Table 6. Estimated Population on Septic Systems in the Watauga River Watershed

County	% of Population on Septic Systems (1990)	Total Population (2010 Census)	Estimated Population on Septic (2010)*
Carter	66.2	57,424	38,187
Johnson	76.6	18,244	13,975
Sullivan	54.8	156,823	85,939
Unicoi	62.0	18,313	11,354
Washington	41.5	122,979	51,036

* Estimate based on 2010 census and 1990 percent of population on septic.

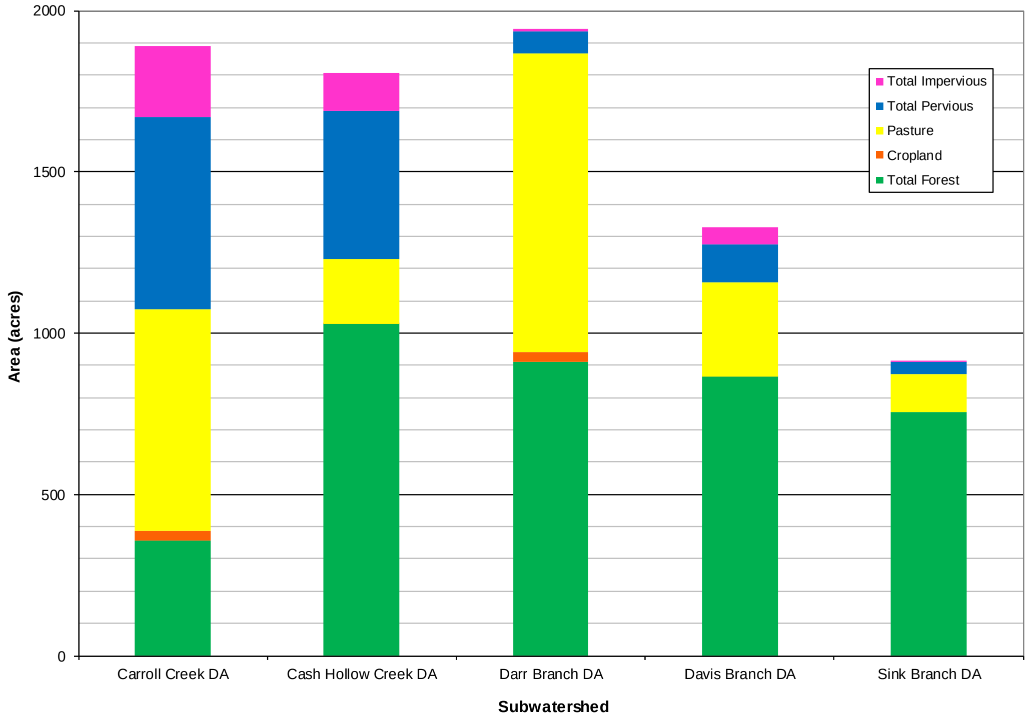

Figure 8. Land Use Area of Watauga River E. coli-Impaired Subwatersheds (less than 4 sq.mi.)

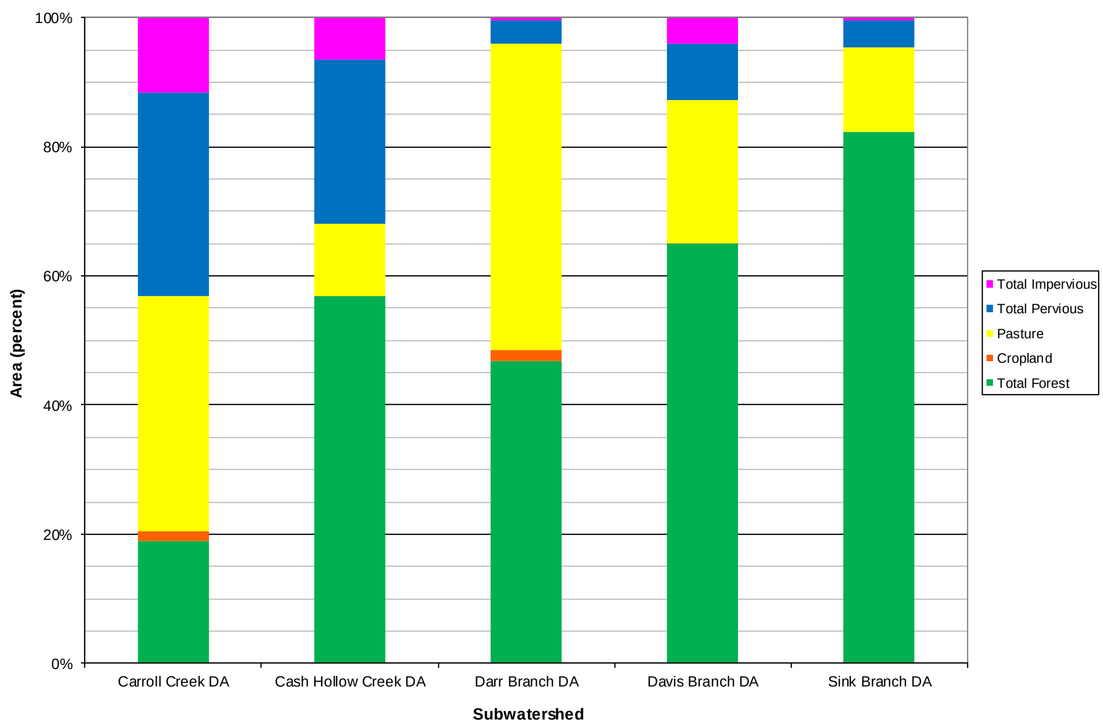

Figure 9. Land Use Percent of Watauga River E. coli-Impaired Subwatersheds (less than 4 sq.mi.)

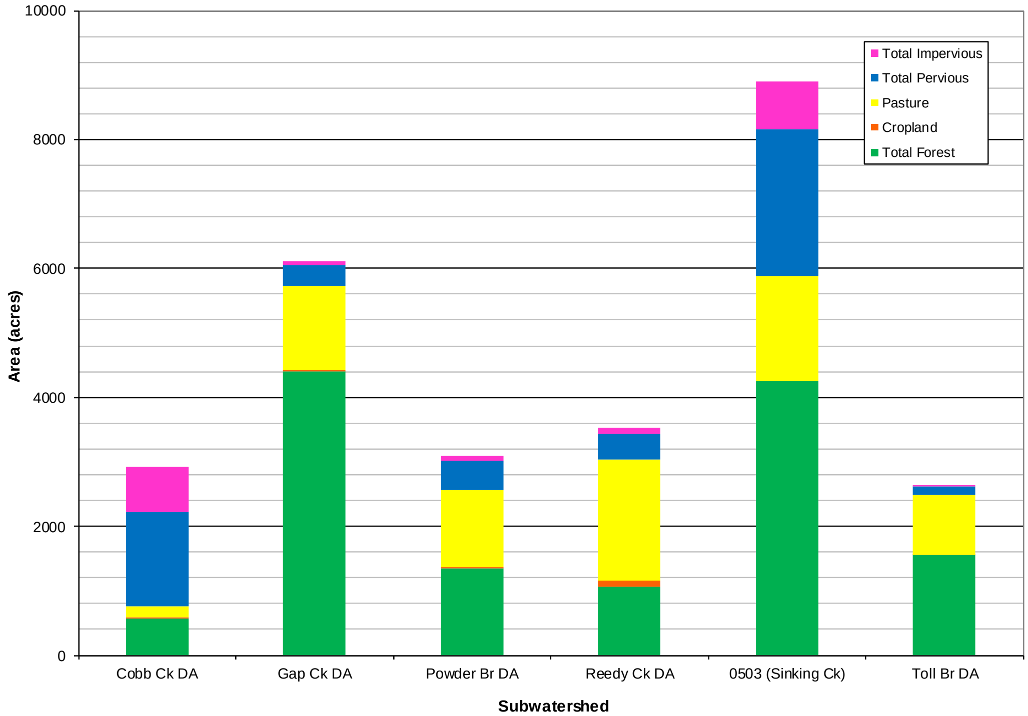

Figure 10. Land Use Area of Watauga River E. coli-Impaired Subwatersheds (greater than 4 sq.mi. & less than 15 sq.mi.)

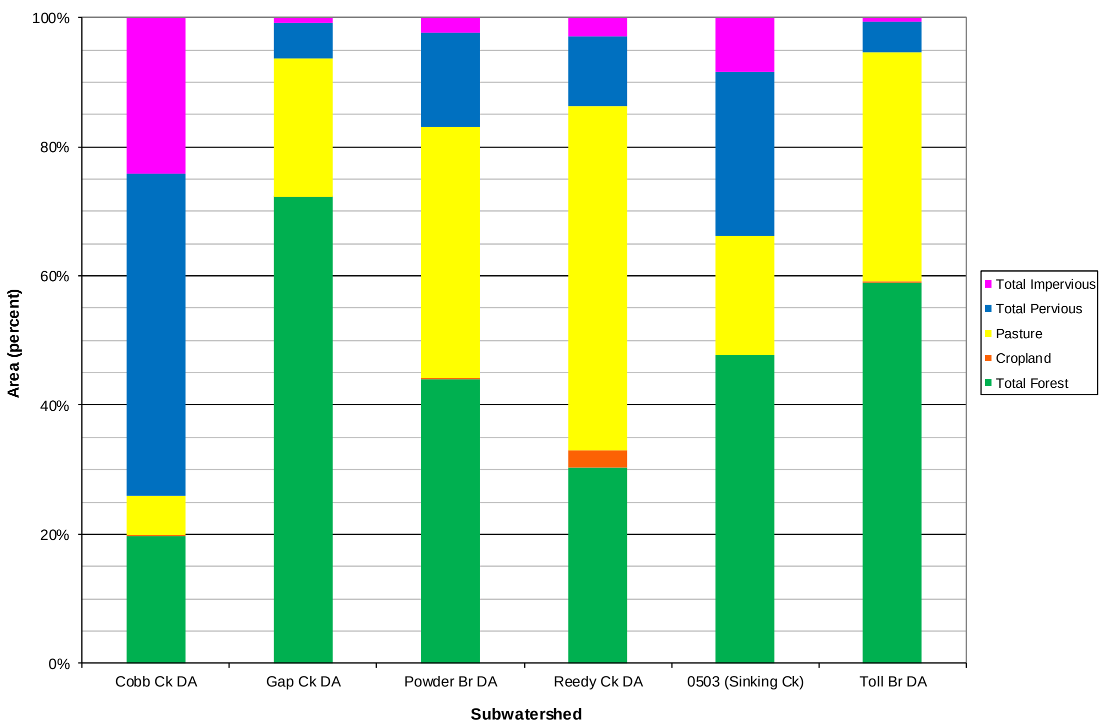

Figure 11. Land Use Percent of Watauga River E. coli-Impaired Subwatershed (greater than 4 sq.mi. & less than 15 sq.mi.)

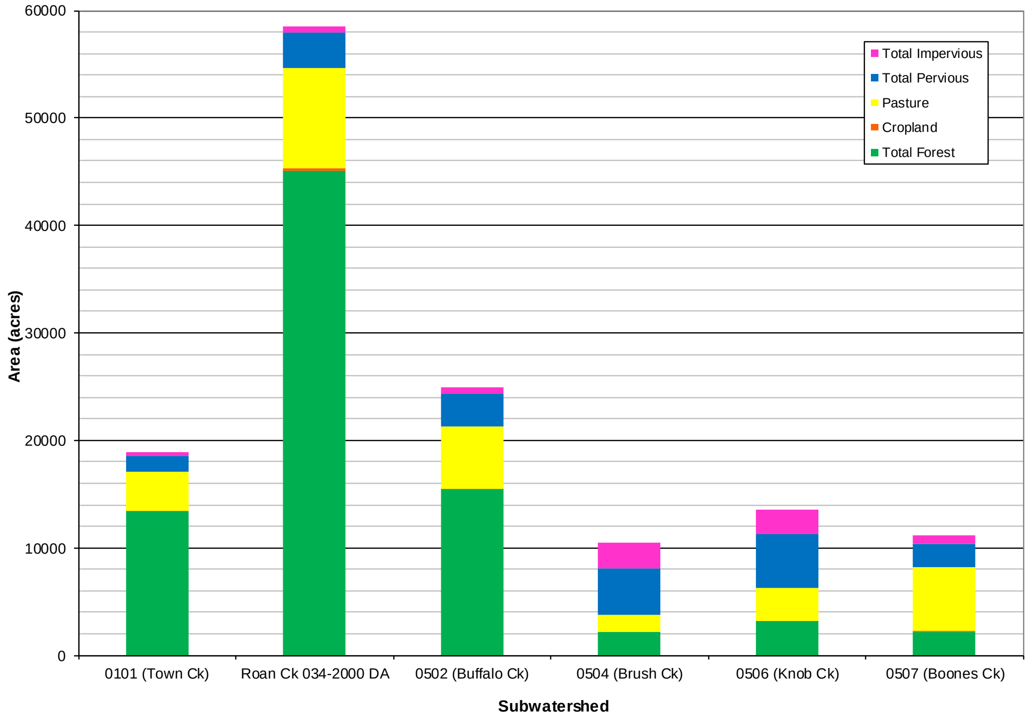

Figure 12. Land Use Area of Watauga River E. coli-Impaired Subwatersheds (greater than 15 sq.mi.)

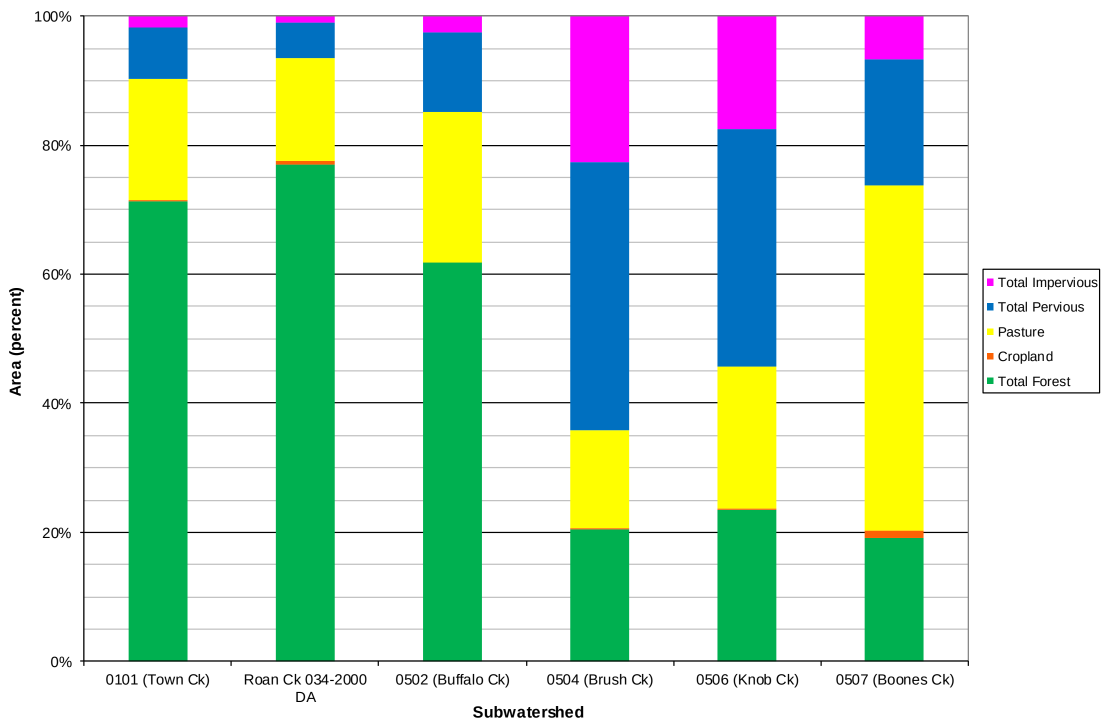

Figure 13. Land Use Percent of Watauga River E. coli-Impaired Subwatershed (greater than 15 sq.mi.)

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOADS

The Total Maximum Daily Load (TMDL) process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), nonpoint source loads (Load Allocations), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma \text{ WLAs} + \Sigma \text{ LAs} + \text{MOS}$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) (http://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol22/pdf/CFR-2011-title40-vol22-sec130-2.pdf) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

This document describes TMDL, Waste Load Allocation (WLA), Load Allocation (LA), and Margin of Safety (MOS) development for waterbodies identified as impaired due to E. coli on the Proposed Final 2014 303(d) list.

8.1 Expression of TMDLs, WLAs, & LAs

In this document, the E. coli TMDL is a daily load expressed as a function of mean daily flow (daily loading function). For implementation purposes, corresponding percent load reduction goals (PLRGs) to decrease E. coli loads to TMDL target levels, within each respective flow zone, are also expressed. WLAs & LAs for precipitation-induced loading sources are also expressed as daily loading functions in CFU/day/acre. Allocations for loading that is independent of precipitation (WLAs for WWTPs and LAs for "other direct sources") are expressed as CFU/day.

8.2 Area Basis for TMDL Analysis

The primary area unit of analysis for TMDL development was the HUC-12 subwatershed containing one or more waterbodies assessed as impaired due to E. coli (as documented on the Proposed Final 2014 303(d) List). In some cases, however, TMDLs may be developed for an impaired waterbody drainage area only. Determination of the appropriate area to use for analysis (see Table 7) was based on a careful consideration of a number of relevant factors, including: 1) location of impaired waterbodies in the HUC-12 subwatershed; 2) land use type and distribution; 3) water quality monitoring data; and 4) the assessment status of other waterbodies in the HUC-12 subwatershed.

Table 7. Determination of Analysis Areas for TMDL Development

Subwatershed (06010103____)	Impaired Waterbody	Area
0101	Town Creek	HUC-12
0102/0104	Roan Creek	DA
0306	Sink Branch	DA
0502	Buffalo Creek	HUC-12
0502	Powder Branch	DA
0502	Toll Branch	DA
0503	Sinking Creek	HUC-12
0504	Brush Creek	HUC-12
0505	Davis Branch	DA
0505	Gap Creek	DA
0506	Cash Hollow Creek	DA
0506	Cobb Creek	DA
0506	Knob Creek	HUC-12
0507	Boones Creek	DA
0507	Carroll Creek	DA
0508	Darr Creek	DA
0508	Reedy Creek	DA

Note: HUC-12 = HUC-12 Subwatershed
DA = Waterbody Drainage Area

8.3 TMDL Analysis Methodology

TMDLs for the Watauga River watershed were developed using load duration curves for analysis of impaired HUC-12 subwatersheds or specific waterbody drainage areas. A load duration curve (LDC) is a cumulative frequency graph that illustrates existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the portion of the waterbody flow zone represented by these existing loads. Load duration curves are considered to be well suited for analysis of periodic monitoring data collected by grab sample. LDCs were developed at monitoring site locations in impaired waterbodies and daily loading functions were expressed for TMDLs, WLAs, LAs, and MOS. In addition, load reductions (PLRGs) for each flow zone were calculated for prioritization of implementation measures according to the methods described in Appendix E.

8.4 Critical Conditions and Seasonal Variation

The critical condition for nonpoint source E. coli loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, E. coli bacteria builds up on the land surface, and is washed off by rainfall. The critical condition for point source loading occurs during periods of low streamflow when dilution is minimized. Both conditions are represented in the TMDL analyses.

The ten-year period from October 1, 2002 to September 30, 2012 was used to simulate flow. This 10-year period contained a range of hydrologic conditions that included both low and high streamflows. Critical conditions are accounted for in the load duration curve analyses by using the entire period of flow and water quality data available for the impaired waterbodies.

In all subwatersheds, water quality data have been collected during most flow ranges. For each subwatershed, the critical flow zone has been identified based on the incremental levels of impairment relative to the target loads. Based on the location of the water quality exceedances on the load duration curves and the distribution of critical flow zones, no one delivery mode for E. coli appears to be dominant for waterbodies in the Watauga River watershed (see Section 9.1.2 and 9.1.3).

Seasonal variation was incorporated in the load duration curves by using the entire simulation period and all water quality data collected at the monitoring stations during the most recent 5-year period. Some water quality data were collected during all seasons.

8.5 Margin of Safety

There are two methods for incorporating MOS in TMDL analysis: a) implicitly incorporate the MOS using conservative model assumptions; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. For development of pathogen TMDLs in the Watauga River watershed, an explicit MOS, equal to 10% of the E. coli water quality targets (ref.: Section 5.0), was utilized for determination of WLAs and LAs:

Instantaneous Maximum (lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters waterbodies):	MOS = 49 CFU/100 ml
Instantaneous Maximum (all other waterbodies):	MOS = 94 CFU/100 ml
30-Day Geometric Mean:	MOS = 13 CFU/100 ml

8.6 Determination of TMDLs

E. coli daily loading functions were calculated for impaired segments in the Watauga River watershed using LDCs to evaluate compliance with the single sample maximum target concentrations according to the procedure in Appendix C. These TMDL loading functions for impaired segments and subwatersheds are shown in Table 8.

8.7 Determination of WLAs & LAs

WLAs for MS4s and LAs for precipitation induced sources of E. coli loading were determined according to the procedures in Appendix C. These allocations represent the available loading <u>after application of the explicit MOS</u>. WLAs for existing WWTPs are equal to their existing NPDES permit limits. Since WWTP permit limits require that E. coli concentrations must comply with water quality criteria (TMDL targets) at the point of discharge (with few exceptions in Tennessee) and recognition that loading from these facilities are generally small in comparison to other loading sources, further reductions were not considered to be warranted. WLAs for CAFOs and LAs for “other direct sources” (non-precipitation induced) are equal to zero. WLAs, & LAs are summarized in Table 8.

Table 8. TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Watauga River Watershed (HUC 06010103)

Impaired Waterbody Name	Impaired Waterbody ID	HUC-12 Subwatershed (06010103___)	TMDL	MOS	WLAs		LAs [c]
					WWTPs [a]	MS4s [b,c]	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/d/ac]	[CFU/d/ac]
Town Creek	TN06010103034 - 0300	0101	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$2.3\times10^{10} \times q_m$	$(1.097 \times 10^{6} \times Q) - (7.592 \times 10^{5})$ [f]	$(1.097 \times 10^{6} \times Q) - (7.592 \times 10^{5})$
Roan Creek	TN06010103034 – 2000	0102/0104 [d]	$1.2 \times 10^{10} \times Q$	$1.2 \times 10^{9} \times Q$	$1.2\times10^{10} \times q_m$	$(1.846 \times 10^{5} \times Q) - (2.448 \times 10^{5})$ [f]	$(1.846 \times 10^{5} \times Q) - (2.448 \times 10^{5})$
Sink Branch	TN06010103020T - 0200	0306 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(2.262 \times 10^{7} \times Q) - (2.519 \times 10^{7} \times q_d)$ [e,f]	$(2.262 \times 10^{7} \times Q) - (2.519 \times 10^{7} \times q_d)$ [e]
Buffalo Creek	TN06010103011 - 1000	0502	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(2.262 \times 10^{7} \times Q) - (2.519 \times 10^{7} \times q_d)$ [e,f]	$(2.262 \times 10^{7} \times Q) - (2.519 \times 10^{7} \times q_d)$ [e]
Powder Branch	TN06010103011 - 0100	0502 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(8.297 \times 10^{5} \times Q) - (9.239 \times 10^{5} \times q_d)$ [e]	$(8.297 \times 10^{5} \times Q) - (9.239 \times 10^{5} \times q_d)$ [e]
Toll Branch	TN06010103011 - 0200	0502 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(6.701 \times 10^{6} \times Q) - (7.462 \times 10^{6} \times q_d)$ [e]	$(6.701 \times 10^{6} \times Q) - (7.462 \times 10^{6} \times q_d)$ [e]
Sinking Creek	TN06010103046 - 1000	0503 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(7.880 \times 10^{6} \times Q) - (8.774 \times 10^{6} \times q_d)$ [e]	$(7.880 \times 10^{6} \times Q) - (8.774 \times 10^{6} \times q_d)$ [e]
Brush Creek	TN06010103009 - 1000	0504	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(2.325 \times 10^{6} \times Q) - (2.588 \times 10^{6} \times q_d)$ [e]	$(2.325 \times 10^{6} \times Q) - (2.588 \times 10^{6} \times q_d)$ [e]
Davis Branch	TN06010103008 - 0400	0505 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(1.981 \times 10^{6} \times Q) - (2.206 \times 10^{6} \times q_d)$ [e]	$(1.981 \times 10^{6} \times Q) - (2.206 \times 10^{6} \times q_d)$ [e]
Gap Creek	TN06010103008 - 0800	0505 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(1.935 \times 10^{7} \times Q) - (2.154 \times 10^{7} \times q_d)$ [e]	$(1.935 \times 10^{7} \times Q) - (2.154 \times 10^{7} \times q_d)$ [e]
Knob Creek	TN06010103635 - 1000	0506	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(3.390 \times 10^{6} \times Q) - (3.775 \times 10^{6} \times q_d)$ [e]	$(3.390 \times 10^{6} \times Q) - (3.775 \times 10^{6} \times q_d)$ [e]
Cobb Creek	TN06010103635 - 0200	0506 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(1.523 \times 10^{6} \times Q) - (1.696 \times 10^{6} \times q_d)$ [e]	$(1.523 \times 10^{6} \times Q) - (1.696 \times 10^{6} \times q_d)$ [e]
Cash Hollow Creek	TN06010103635 - 0100	0506 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(7.094 \times 10^{6} \times Q) - (7.899 \times 10^{6} \times q_d)$ [e]	$(7.094 \times 10^{6} \times Q) - (7.899 \times 10^{6} \times q_d)$ [e]
Boones Creek	TN06010103006 - 1000	0507 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(1.145 \times 10^{7} \times Q) - (1.275 \times 10^{7} \times q_d)$ [e]	$(1.145 \times 10^{7} \times Q) - (1.275 \times 10^{7} \times q_d)$ [e]
Carroll Creek	TN06010103006 - 0100	0507 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(1.862 \times 10^{6} \times Q) - (2.074 \times 10^{6} \times q_d)$ [e]	$(1.862 \times 10^{6} \times Q) - (2.074 \times 10^{6} \times q_d)$ [e]

Table 8 (cont'd). TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Watauga River Watershed (HUC 06010103)

Impaired Waterbody Name	Impaired Waterbody ID	HUC-12 Subwatershed (06010103___)	TMDL	MOS	WLAs		LAs [c]
					WWTPs [a]	MS4s [b,c]	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/d/ac]	[CFU/d/ac]
Darr Creek	TN06010103001T - 0100	0508 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(1.065 \times 10^{7} \times Q) - (1.186 \times 10^{7} \times q_d)$ [e]	$(1.065 \times 10^{7} \times Q) - (1.186 \times 10^{7} \times q_d)$ [e]
Reedy Creek	TN06010103061 - 1000	0508 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(5.871 \times 10^{6} \times Q) - (6.537 \times 10^{6} \times q_d)$ [e]	$(5.871 \times 10^{6} \times Q) - (6.537 \times 10^{6} \times q_d)$ [e]

Notes: Q = Mean Daily In-stream Flow (cfs).
q_m = Mean Daily WWTP Discharge (cfs)
q_d = Facility (WWTP) Design Flow (cfs)

a. WLAs for WWTPs are expressed as E. coli loads (CFU/day). All current and future WWTPs must meet water quality standards as specified in their NPDES permit.
b. Applies to any MS4 discharge loading in the subwatershed. Future MS4s will be assigned waste load allocations (WLAs) consistent with load allocations (LAs) assigned to precipitation induced nonpoint sources. Compliance is achieved by meeting in-stream single-sample E. coli concentrations of ≤ 941 CFU/100 mL (or 487 CFU/100 mL for lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters). Delisting is achieved by meeting in-stream geomean sample E. coli concentrations of ≤ 126 CFU/100 mL.
c. WLAs and LAs expressed as a "per acre" load are calculated based on the drainage area at the pour point of the HUC-12 subwatershed or drainage area (see Table A-1). As regulated MS4 area increases (due to future growth and/or new MS4 designation), unregulated LA area decreases by an equivalent amount. The sum will continue to equal total subwatershed area.
d. Waterbody Drainage Area (DA) is not coincident with HUC-12(s).
e. No WWTPs currently discharging into or upstream of the waterbody. (Expression is future growth term for new WWTPs.)
f. No MS4s currently located in the subwatershed drainage area. (Expression is future growth term for expanding or newly designated MS4s.)

9.0 IMPLEMENTATION PLAN

The TMDLs, WLAs, and LAs developed in Section 8 are intended to be the first phase of a long-term effort to restore the water quality of impaired waterbodies in the Watauga River watershed through reduction of excessive E. coli loading. Adaptive management methods, within the context of the State's rotating watershed management approach, will be used to modify TMDLs, WLAs, and LAs as required to meet water quality goals.

TMDL implementation activities will be accomplished within the framework of Tennessee's Watershed Approach (ref: http://www.tn.gov/environment/water/watersheds/index.shtml). The Watershed Approach is based on a five-year cycle and encompasses planning, monitoring, assessment, TMDLs, WLAs/LAs, and permit issuance. It relies on participation at the federal, state, local and non-governmental levels to be successful.

9.1 Application of Load Duration Curves for Implementation Planning

The Load Duration Curve (LDC) methodology (Appendix C) is a form of water quality analysis and presentation of data that aids in guiding implementation by targeting management strategies for appropriate flow conditions. One of the strengths of this method is that it can be used to interpret possible delivery mechanisms of E. coli by differentiating between point and nonpoint source problems. The load duration curve analysis can be utilized for implementation planning. See Cleland (2003) for further information on duration curves and TMDL development, and: http://www.tmdls.net/tipstools/docs/TMDLsCleland.pdf.

9.1.1 Flow Zone Analysis for Implementation Planning

A major advantage of the duration curve framework in TMDL development is the ability to provide meaningful connections between allocations and implementation efforts (USEPA, 2006). Because the flow duration interval serves as a general indicator of hydrologic condition (i.e., wet versus dry and to what degree), allocations and reduction goals can be linked to source areas, delivery mechanisms, and the appropriate set of management practices. The use of duration curve zones (e.g., high flow, moist, mid-range, dry, and low flow) allows the development of allocation tables (USEPA, 2006) (Appendix E), which can be used to guide potential implementation actions to most effectively address water quality concerns.

For the purposes of implementation strategy development, available E. coli data are grouped according to flow zones, with the number of flow zones determined by the HUC-12 subwatershed or drainage area size, the total contributing area (for non-headwater HUC-12s), and/or the baseflow characteristics of the waterbody. In general, for drainage areas greater than 40 square miles, the duration curves will be divided into five zones (Figure 14): high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-60%), dry conditions (60-90%), and low flows (90-100%). For smaller drainage areas, flows occurring in the low flow zone (baseflow conditions) are often extremely low and difficult to measure accurately. In many small drainage areas, extreme dry conditions are characterized by zero flow for a significant percentage of time. For this reason, the low flow zone is best characterized as a broader range of conditions (or percent time) with subsequently fewer flow zones. Therefore, for most HUC-12 subwatershed drainage areas less than 40 square miles, the duration curves will be divided into four zones: high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-70%), and low flows (70-100%). Some small (<40 mi^2) waterbody drainage areas have sustained baseflow (no zero flows) throughout their period of record. For these waterbodies, the duration curves will be divided into five zones.

Given adequate data, results (allocations and percent load reduction goals) will be calculated for all flow zones; however, less emphasis is placed on the upper 10% flow range for pathogen (E. coli) TMDLs and implementation plans. The highest 10 percent flows, representing flood conditions, are considered non-recreational conditions: unsafe for wading and swimming. Humans are not expected to enter the water due to the inherent hazard from high depths and velocities during these flow conditions. As a rule of thumb, the United States Geological Survey (USGS) *National Field Manual for the Collection of Water Quality Data* (Lane, 1997) advises its personnel not to attempt to wade a stream for which values of depth (ft) multiplied by velocity (ft/s) equal or exceed 10 ft^2/s to collect a water sample. Few observations are typically available to estimate loads under these adverse conditions due to the difficulty and danger of sample collection. Therefore, in general, the 0-10% flow range is beyond the scope of pathogen TMDLs and subsequent implementation strategies.

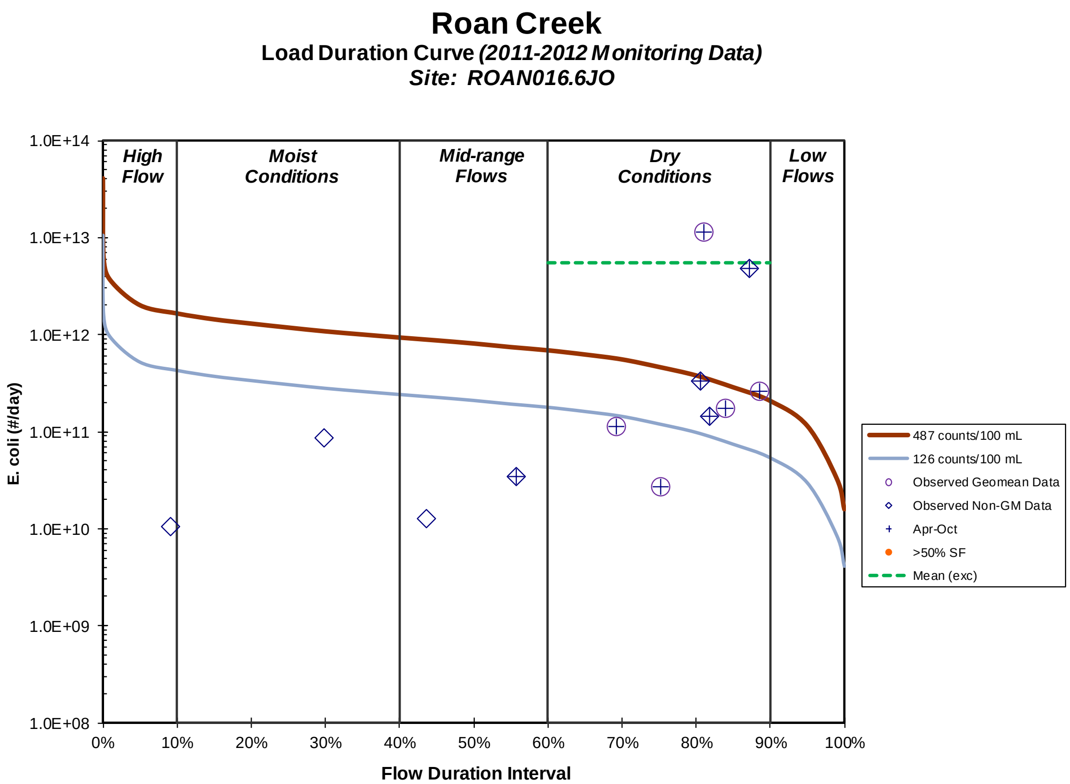

Figure 14. Five-Zone Flow Duration Curve for Roan Creek at RM16.6

9.1.2 Existing Loads and Percent Load Reductions

Each impaired waterbody has a characteristic set of pollutant sources and existing loading conditions that vary according to flow conditions. In addition, maximum allowable loading (assimilative capacity) of a waterbody varies with flow. Therefore, existing loading, allowable loading, and percent load reduction expressed at a single location on the LDC (for a single flow condition) do not appropriately represent the TMDL in order to address all sources under all flow conditions (i.e., at all times) to satisfy implementation objectives. The LDC approach provides a methodology for determination of assimilative capacity and existing loading conditions of a waterbody for each flow zone. Subsequently, each flow zone, and the sources contributing to impairment under the corresponding flow conditions, can be evaluated independently. Lastly, the critical flow zone (with the highest percent load reduction goal and/or the highest percent of samples exceeding the TMDL target) can be identified for prioritization of implementation actions.

Existing loading is calculated for each individual water quality sample as the product of the sample flow (cfs) times the single sample E. coli concentration (times a conversion factor). A percent load reduction is calculated for each water quality sample exceeding the single sample maximum water quality criterion as that required to reduce the existing loading to the product of the sample flow (cfs) times the single sample maximum water quality standard (times a conversion factor). Samples with negative percent load reductions (non-exceedance: concentration below the single sample maximum water quality criterion) are not factored into the calculation of the percent load reduction goals (PLRGs). The PLRG for a given flow zone is calculated as the mean of all the positive percent load reductions for a given flow zone. See Appendix E.

9.1.3 Critical Conditions

The critical condition for each impaired waterbody is defined as the flow zone with the largest PLRG and/or percent exceedance, excluding the “high flow” zone because these extremely high flows are not representative of recreational flow conditions, as described in Section 9.1.1. If the PLRG and/or percent exceedance in this zone is greater than all the other zones, the zone with the second highest PLRG and/or percent exceedance will be considered the critical flow zone. The critical conditions are such that if water quality standards were met under those conditions, they would likely be met overall.

9.2 Point Sources

9.2.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

All present and future discharges from industrial and municipal wastewater treatment facilities are required to be in compliance with the conditions of their NPDES permits at all times, including elimination of bypasses and overflows. With few exceptions, in Tennessee, permit limits for treated sanitary wastewater require compliance with coliform water quality standards (ref: Section 5.0) prior to discharge. No additional reduction is required. WLAs for WWTPs are derived from mean daily facility flows and permitted E. coli limits and are expressed as daily loads in CFU per day.

9.2.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For present and future regulated discharges from municipal separate storm sewer systems (MS4s), WLAs are and will be implemented through Phase I & II MS4 permits. These permits will require the development and implementation of a Storm Water Management Program (SWMP) that will reduce the discharge of pollutants to the "maximum extent practicable" and not cause or contribute to violations of State water quality standards. Both the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2010) and the TDOT individual MS4 permit (TNS077585) require SWMPs to include minimum control measures. The permits also contain requirements regarding control of discharges of pollutants of concern into impaired waterbodies, implementation of provisions of approved TMDLs, and descriptions of methods to evaluate whether storm water controls are adequate to meet the requirements of approved TMDLs.

For guidance on the six minimum control measures for MS4s regulated under Phase I or Phase II, a series of fact sheets are available at: http://water.epa.gov/polwaste/npdes/swbmp/index.cfm.

For further information on Tennessee's *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems*, see: http://www.tn.gov/environment/water/docs/wpc/tns000000_MS4_phase_ii_2010.pdf.

In order to evaluate SWMP effectiveness and demonstrate compliance with specified WLAs, MS4s must develop and implement appropriate monitoring programs. According to the MS4 general permit (TDEC, 2010), "If an MS4 discharges into a water body with an approved or established TMDL, the Storm Water Management Program must include BMPs specifically targeted to achieve the wasteload allocations prescribed by the TMDL. A monitoring component to assess the effectiveness of the BMPs in achieving the wasteload allocations must also be included in the SWMP." An effective monitoring program could include:

- Analytical monitoring of pollutants of concern in receiving waterbodies, both upstream and downstream of MS4 discharges, at sufficient frequency (e.g., monthly) and duration to characterize MS4 pollutant source contribution, or lack thereof.
- Stormwater monitoring at selected outfalls that is representative of particular land uses or geographical areas that contribute to pollutant loading before and after implementation of pollutant control measures.
- Monitoring to support evaluation of BMP effectiveness and quantification of percent removal of pollutants of concern.
- When and where pollutant loading reduction efforts have potentially achieved target maximum loading for E. coli, intensive collection of pollutant monitoring data during the recreation season (June – September) at sufficient frequency to support calculation of the geometric mean for waterbody delisting.

When applicable, the appropriate DWR Environmental Field Office should be consulted for assistance in the determination of monitoring strategies, locations, frequency, and methods within 12 months after the approval date of TMDLs or designation as a regulated MS4. Details of the monitoring plans and monitoring data should be included in annual reports required by MS4 permits.

9.2.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

WLAs provided to most CAFOs will be implemented through the appropriate CAFO State Operating Permit or the facility's individual permit. Provisions of the SOP include development and implementation of Nutrient Management Plans (NMPs) and requirements for CAFO liquid waste management systems. For further information, see: https://www.tn.gov/environment/permits/cafo.shtml.

9.3 Nonpoint Sources

The Tennessee Department of Environment & Conservation (TDEC) has no direct regulatory authority over most nonpoint source (NPS) discharges. Reductions of E. coli loading from nonpoint sources will be achieved using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. There are links to a number of publications and information resources on EPA's Nonpoint Source Pollution web page (http://water.epa.gov/polwaste/nps/) relating to the implementation and evaluation of nonpoint source pollution control measures.

Local citizen-led and implemented management measures have the potential to provide the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. A public watershed meeting conducted in November 2014 brought together numerous residents and stakeholder groups in the Watauga Watershed. The Boone Watershed Partnership, Inc. (BWP) is one of those groups. The BWP is a 501(c)(3) nonprofit organization that works with local users, regional, state and federal entities, educators and others to identify and address water resource issues in the Boone Watershed. The BWP, working with the City of Johnson City, received an EPA 319 grant to address non-point sources of pollution in Sinking Creek, a state-listed 303(d) stream. Phase 1 of the Sinking Creek Project included 24 sewer hook-ups, 5 septic tank/drainfield repairs, and 1 agricultural project. Phase 2 of the project involves enhancement of an existing wetland owned by the City. This wetlands enhancement site, which is part of a 28 acre parcel, features many native plants and trees, and will serve as a natural laboratory for area students. Results of a stream survey conducted in July 2013 by TDEC were found to be in the acceptable range. Additional information about the Boone Watershed Partnership is available at: http://boonewatershed.org/

9.3.1 Urban Nonpoint Sources

Management measures to reduce pathogen loading from urban nonpoint sources are similar to those recommended for MS4s (Sect. 9.2.2). Specific categories of urban nonpoint sources include storm water, illicit discharges, septic systems, pet waste, and wildlife.

Storm water: Most mitigation measures for storm water are not designed specifically to reduce bacteria concentrations (ENSR, 2005). Instead, BMPs are typically designed to remove sediment and other pollutants. Bacteria in stormwater runoff are, however, often attached to particulate matter. Therefore, treatment systems that remove sediment may also provide reductions in bacteria concentrations.

Illicit discharges: Removal of illicit discharges to storm sewer systems, particularly of sanitary wastes, is an effective means of reducing pathogen loading to receiving waters (ENSR, 2005). These include intentional illegal connections from commercial or residential buildings, failing septic systems, and improper disposal of sewage from campers and boats.

Septic systems: When properly installed, operated, and maintained, septic systems effectively reduce pathogen concentrations in sewage. To reduce the release of pathogens, practices can be employed to maximize the life of existing systems, identify failed systems, and replace or remove failed systems (USEPA, 2005a). Alternatively, the installation of public sewers may be appropriate.

Pet waste: If the waste is not properly disposed of, these bacteria can wash into storm drains or directly into water bodies and contribute to pathogen impairment. Encouraging pet owners to properly collect and dispose of pet waste is the primary means for reducing the impact of pet waste (USEPA, 2002b).

Wildlife: Reducing the impact of wildlife on pathogen concentrations in waterbodies generally requires either reducing the concentration of wildlife in an area or reducing their proximity to the waterbody (ENSR, 2005). The primary means for doing this is to eliminate human inducements for congregation. In addition, in some instances population control measures may be appropriate.

Three additional urban nonpoint source resource documents provided by EPA are:

National Management Measures to Control Nonpoint Source Pollution from Urban Areas (http://water.epa.gov/polwaste/nps/urban/index.cfm) helps citizens and municipalities in urban areas protect bodies of water from polluted runoff that can result from everyday activities. The scientifically sound techniques it presents are among the best practices known today. The guidance will also help states to implement their nonpoint source control programs and municipalities to implement their Phase II Storm Water Permit Programs (Publication Number EPA 841-B-05-004, November 2005).

The Use of Best Management Practices (BMPs) in Urban Watersheds (http://medina.cee.duke.edu/CE123/600r04184.pdf) is a comprehensive literature review on commonly used urban watershed Best Management Practices (BMPs) that heretofore was not consolidated. The purpose of this document is to serve as an information source to individuals and agencies/municipalities/watershed management groups/etc. on the existing state of BMPs in urban storm water management (Publication Number EPA/600/R-04/184, September 2004).

National Menu of Stormwater Best Management Practices (http://water.epa.gov/polwaste/npdes/swbmp/index.cfm) is based on the Storm Water Phase II Rule's six minimum control measures and was first released in October 2000. As recently as July, 2014, EPA has renamed, reorganized, updated, and enhanced the features of the website, including addition of new fact sheets and revisions of existing fact sheets.

9.3.2 Agricultural Nonpoint Sources

BMPs have been utilized in the Watauga River watershed to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. These BMPs (e.g., animal waste management systems, waste utilization, stream stabilization, fencing, heavy use area treatment, livestock exclusion, etc.) may have contributed to reductions in in-stream concentrations of coliform bacteria in one or more Watauga River watershed E. coli-impaired subwatersheds during the TMDL evaluation period. The Tennessee Department of Agriculture (TDA) keeps a database of BMPs implemented in Tennessee. Those listed in the Watauga River Watershed are shown in Figure 15. It is recommended that additional information (e.g., livestock access to streams, manure application practices, etc.) be provided and evaluated to better identify and quantify agricultural sources of coliform bacteria loading in order to increase the success of future remediation efforts.

It is further recommended that additional BMPs be implemented and monitored to document performance in reducing coliform bacteria loading to surface waters from agricultural sources. Demonstration sites for various types of BMPs should be established and maintained, and their performance (in source reduction) evaluated prior to recommendations for utilization for subsequent implementation. E. coli sampling and monitoring are recommended during low-flow (baseflow) and storm periods at sites with and without BMPs and/or before and after implementation of BMPs.

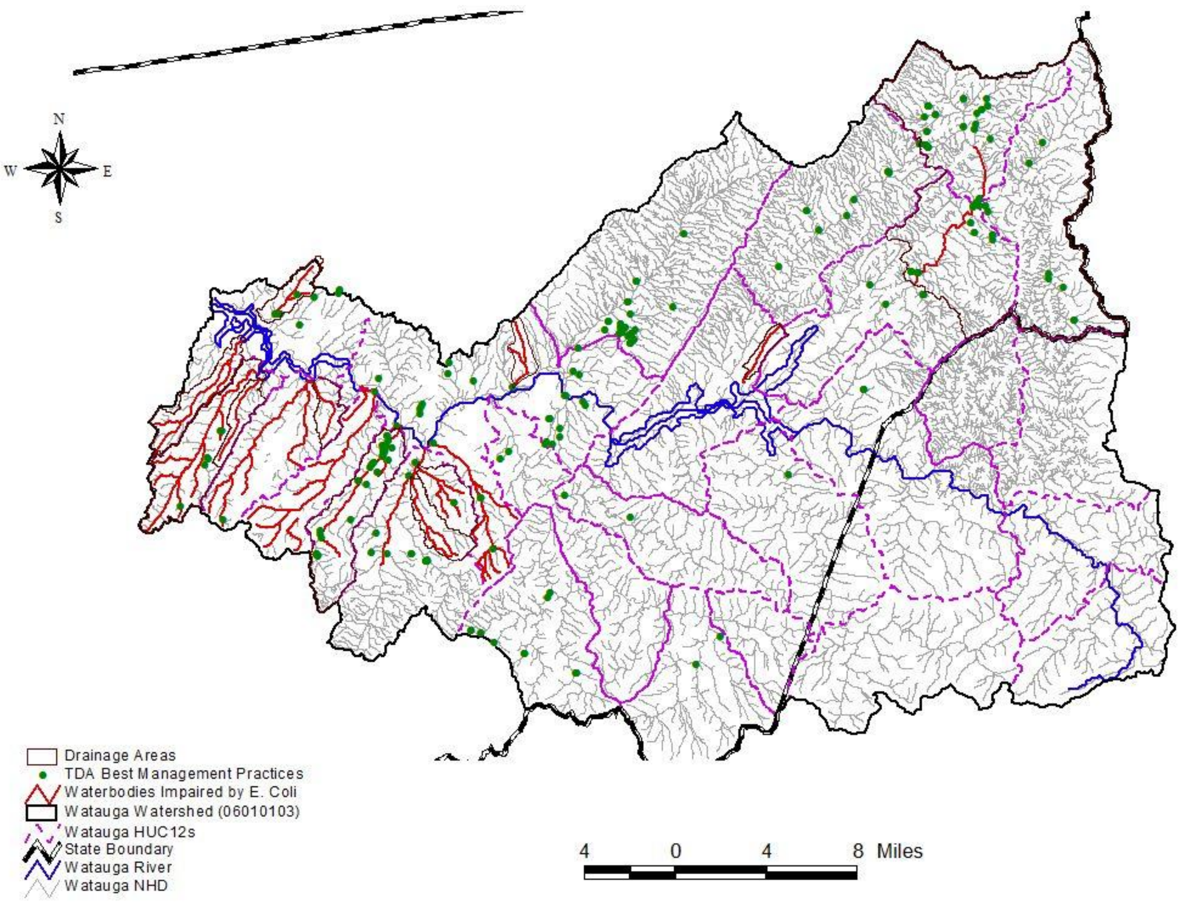

Figure 15. TDA Best Management Practices located in the Watauga River Watershed

For additional information on agricultural BMPs in Tennessee, see: http://www.tn.gov/agriculture/water/bmpa.shtml. An additional agricultural nonpoint source resource provided by EPA is *National Management Measures to Control Nonpoint Source Pollution from Agriculture* (http://water.epa.gov/polwaste/nps/agriculture/agmm_index.cfm): a technical guidance and reference document for use by State, local, and tribal managers in the implementation of nonpoint source pollution management programs. It contains information on the best available, economically achievable means of reducing pollution of surface and groundwater from agriculture (EPA 841-B-03-004, July 2003).

9.3.3 Other Nonpoint Sources

Additional nonpoint source references (not specifically addressing urban and/or agricultural sources) provided by EPA include:

National Management Measures to Control Nonpoint Source Pollution from Forestry (http://water.epa.gov/polwaste/nps/forestry/forestrymgmt_index.cfm) helps forest owners protect lakes and streams from polluted runoff that can result from forestry activities. These scientifically sound techniques are the best practices known today. The report will also help states to implement their nonpoint source control programs (EPA 841-B-05-001, May 2005).

In addition, the EPA website, http://www.epa.gov/owow/nps , contains a list of guidance documents endorsed by the Nonpoint Source Control Branch at EPA headquarters. The list includes documents addressing urban, agriculture, forestry, marinas, stream restoration, nonpoint source monitoring, and funding.

9.4 Additional Monitoring

Additional monitoring and assessment activities are recommended to determine whether implementation of TMDLs, WLAs, & LAs will result in achievement of in-stream water quality targets for E. coli.

9.4.1 TMDL Monitoring

Activities recommended for the Watauga River watershed:

- Evaluate the effectiveness of implementation measures (see Sect. 9.6) and include BMP performance analysis and monitoring by permittees and stakeholders.
- Provide additional data to clarify status of ambiguous sites (e.g., geometric mean data) for potential listing.
- Continue ambient (long-term) monitoring at appropriate sites and key locations.
- Collection of E. coli data at sufficient frequency to support calculation of the geometric mean, as described in Tennessee's General Water Quality Criteria (TDEC, 2013), is encouraged when water quality improvement has been realized and delisting is probable.

Comprehensive water quality monitoring activities include sampling during all seasons and a broad range of flow and meteorological conditions. In addition, collection of E. coli data at sufficient frequency to support calculation of the geometric mean, as described in Tennessee's General Water Quality Criteria (TDEC, 2013), is encouraged when reductions are expected to be sufficient to support delisting. Finally, for individual monitoring locations, where historical E. coli data are greater than 2419 colonies/100 mL (or future samples are anticipated to be), a 1:10 (or 1:100) dilution should be performed as described in Protocol A of the *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC, 2011).

9.4.2 Source Identification

An important aspect of E. coli load reduction activities is the accurate identification of the actual sources of pollution. In cases where the sources of E. coli impairment are not readily apparent, Microbial Source Tracking (MST) is one approach to determining the sources of fecal pollution and E. coli affecting a waterbody. Those methods that use bacteria as target organisms are also known as Bacterial Source Tracking (BST) methods. This technology is recommended for source identification in E. coli impaired waterbodies.

Bacterial Source Tracking is a collective term used for various emerging biochemical, chemical, and molecular methods that have been developed to distinguish sources of human and non-human fecal pollution in environmental samples (Shah, 2004). In general, these methods rely on genotypic (also known as "genetic fingerprinting"), or phenotypic (relating to the physical characteristics of an organism) distinctions between the bacteria of different sources. Three primary genotypic techniques are available for BST: ribotyping, pulsed field gel electrophoresis (PFGE), and polymerase chain reaction (PCR). Phenotypic techniques generally involve an antibiotic resistance analysis (Hyer, 2004).

The USEPA has published a fact sheet that discusses BST methods and presents examples of BST application to TMDL development and implementation (USEPA, 2002b). Various BST projects and descriptions of the application of BST techniques used to guide implementation of effective BMPs to remove or reduce fecal contamination are presented. The fact sheet can be found on the following EPA website: http://water.epa.gov/scitech/wastetech/upload/2002_10_15_mtb_bacsortk.pdf.

A recent article about "Advancements in Bacterial Source Tracking" is available at: http://www.stormh2o.com/SW/Articles/25460.aspx. This article provides information about: (1) general types of BST methods, and comparison of the advantages and disadvantages of several of these methodologies, (2) the value of adopting BST techniques in an effort to focus system improvements in a way that reduces costs by placing an emphasis on the right source(s) of bacteria (i.e., human versus non-human), and (3) recent advances in BST technology, including a list of reading sources to study this topic in greater detail.

A multi-disciplinary group of researchers at the University of Tennessee, Knoxville (UTK) has developed and tested a series of different microbial assay methods based on real-time PCR to detect fecal bacterial concentrations and host sources in water samples (Layton, 2006). The assays have been used in a study of fecal contamination and have proven useful in identification of areas where cattle represent a significant fecal input and in development of BMPs. It is expected that these types of assays could have broad applications in monitoring fecal impacts from Animal Feeding Operations, as well as from wildlife and human sources. Additional information can be found on the following UTK website: http://web.utk.edu/~hydro/JournalPapers/Layton06AEM.pdf . BST technology was utilized in a study conducted in Stock Creek (Little River watershed) (Layton, 2004). Microbial source tracking using real-time PCR assays to quantify *Bacteroides* 16S rRNA genes was used to determine the percent of fecal contamination attributable to cattle. E. coli loads attributable to cattle were calculated for each of nine sampling sites in the Stock Creek subwatershed on twelve sampling dates. At the site on High Bluff Branch (tributary to Stock Creek), none of the sample dates had E. coli loads attributable to cattle above the threshold. This suggests that at this site removal of E. coli attributable to cattle would have little impact on the total E. coli loads. The E. coli load attributable to cattle made a large contribution to the total E. coli load at each of the eight remaining sampling sites. At two of the sites (STOCK005.3KN and GHOLL000.6KN), 50–75% of the E. coli attributable to cattle loads alone was above the 126 CFU/100mL threshhold. This suggests that removal of the E. coli attributable to cattle at these sites would reduce the total E. coli load to acceptable limits.

9.5 Source Area Implementation Strategy

Implementation strategies are organized according to the dominant landuse type and the sources associated with each (Table 9 and Appendix E). Additional considerations for classification of source area type include waterbody assessment information from TDEC's ADB and subsequent Pollutant Source designation on the 303(d) List. Each HUC-12 subwatershed and waterbody drainage area is grouped and targeted for implementation based on this source area classification. Three primary categories are identified: predominantly urban, predominantly agricultural, and mixed urban/agricultural. See Appendix A for information regarding landuse distributation of impaired subwatersheds. For the purpose of implementation evaluation, urban is defined as residential, commercial, and industrial landuse areas (landuse classifications: low, medium, and high intensity development) with predominant source categories such as point sources (WWTPs), collection systems/septic systems (including SSOs and CSOs), and urban stormwater runoff associated with MS4s. Agricultural is defined as cropland and pasture, with predominant source categories associated with livestock and manure management activities. A fourth category (infrequent) is associated with forested (including non-agricultural undeveloped and unaltered [by humans]) landuse areas with the predominant source category being wildlife.

All impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas have been classified according to their respective source area types in Table 9. The implementation for each area will be prioritized according to the guidance provided in Sections 9.5.1 and 9.5.2, below. For all impaired waterbodies, the determination of source area types serves to identify the predominant sources contributing to impairment (i.e., those that should be targeted initially for implementation). However, it is not intended to imply that sources in other landuse areas are not contributors to impairment and/or to grant an exemption from addressing other source area contributions with implementation strategies and corresponding load reduction. For mixed use areas, implementation will follow the guidance established for both urban and agricultural areas, at a minimum.

Appendix E provides source area implementation examples for urban and agricultural subwatersheds, development of percent load reduction goals, and determination of critical flow zones (for implementation prioritization) for E. coli impaired waterbodies. Load duration curve analyses (TMDLs, WLAs, LAs, and MOS) and percent load reduction goals for all flow zones for all E. coli impaired waterbodies in the Watauga River watershed are summarized in Table E-62.

9.5.1 Urban Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas classified as predominantly urban, implementation strategies for E. coli load reduction will initially and primarily target source categories similar to those listed in Table 10 (USEPA, 2006). Table 10 presents example urban area management practices and the corresponding potential relative effectiveness under each of the hydrologic flow zones. Each implementation strategy addresses a range of flow conditions and targets point sources, nonpoint sources, or a combination of each. For each waterbody, the existing loads and corresponding PLRG for each flow zone are calculated according to the method described in Section E.1. The resulting determination of the critical flow zone further focuses the types of urban management practices appropriate for development of an effective load reduction strategy for a particular waterbody.

Table 9. Source area types for waterbody drainage area analyses

HUC-12 / Waterbody	Source Area Type*			
	Urban	Agriculture	Mixed	Forested
0101 / Town Creek			✓	
0102+0104 / Roan Creek			✓	
0306 / Sink Branch			✓	
0502 / Buffalo Creek			✓	
0502 / Powder Branch			✓	
0502 / Toll Branch			✓	
0503 / Sinking Creek	✓			
0504 / Brush Creek	✓			
0505 / Davis Branch			✓	
0505 / Gap Creek			✓	
0506 / Cash Hollow Creek	✓			
0506 / Cobb Creek	✓			
0506 / Knob Creek	✓			
0507 / Boones Creek			✓	
0507 / Carroll Creek			✓	
0508 / Darr Creek		✓		
0508 / Reedy Creek		✓		

* All waterbodies potentially have significant source contributions from other source type/landuse areas.

9.5.2 Agricultural Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas classified as predominantly agricultural, implementation strategies for E. coli load reduction will initially and primarily target source categories similar to those listed in Table 11 (USDA, 1988). Table 11 presents example agricultural area management practices and the corresponding potential relative effectiveness under each of the hydrologic flow zones. Each implementation strategy addresses a range of flow conditions and targets point sources, nonpoint sources, or a combination of each. For each waterbody, the existing loads and corresponding PLRG for each flow zone are calculated according to the method described in Section E.2. The resulting determination of the critical flow zone further focuses the types of agricultural management practices appropriate for development of an effective load reduction strategy for a particular waterbody.

Table 10. Example Urban Area Management Practice/Hydrologic Flow Zone Considerations

Management Practice	Duration Curve Zone (Flow Zone)				
	High	Moist	Mid-Range	Dry	Low
Bacteria source reduction					
Remove illicit discharges			L	M	H
Address pet & wildlife waste		H	M	M	L
Combined sewer overflow management					
Combined sewer separation		H	M	L	
CSO prevention practices		H	M	L	
Sanitary sewer system					
Infiltration/Inflow mitigation	H	M	L	L	
Inspection, maintenance, and repair		L	M	H	H
SSO repair/abatement	H	M	L		
Illegal cross-connections					
Septic system management					
Managing private systems		L	M	H	M
Replacing failed systems		L	M	H	M
Installing public sewers		L	M	H	M
Storm water infiltration/retention					
Infiltration basin		L	M	H	
Infiltration trench		L	M	H	
Infiltration/Biofilter swale		L	M	H	
Storm Water detention					
Created wetland		H	M	L	
Low impact development					
Disconnecting impervious areas		L	M	H	
Bioretention	L	M	H	H	
Pervious pavement		L	M	H	
Green Roof		L	M	H	
Buffers		H	H	H	
New/existing on-site wastewater treatment systems					
Permitting & installation programs		L	M	H	M
Operation & maintenance programs		L	M	H	M
Other					
Point source controls		L	M	H	H
Landfill control		L	M	H	
Riparian buffers		H	H	H	
Pet waste education & ordinances		M	H	H	L
Wildlife management		M	H	H	L
Inspection & maintenance of BMPs	L	M	H	H	L

Note: Potential relative importance of management practice effectiveness under given hydrologic condition (*H: High, M: Medium, L: Low*)

Table 11. Example Agricultural Area Management Practice/Hydrologic Flow Zone Considerations

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
Grazing Management					
Prescribed Grazing (528A)	H	H	M	L	
Pasture & Hayland Mgmt (510)	H	H	M	L	
Deferred Grazing (352)	H	H	M	L	
Planned Grazing System (556)	H	H	M	L	
Proper Grazing Use (528)	H	H	M	L	
Proper Woodland Grazing (530)	H	H	M	L	
Livestock Access Limitation					
Livestock Exclusion (472)			M	H	H
Fencing (382)			M	H	H
Stream Crossing			M	H	H
Alternate Water Supply					
Pipeline (516)			M	H	H
Pond (378)			M	H	H
Trough or Tank (614)			M	H	H
Well (642)			M	H	H
Spring Development (574)			M	H	H
Manure Management					
Managing Barnyards	H	H	M	L	
Manure Transfer (634)	H	H	M	L	
Land Application of Manure	H	H	M	L	
Composting Facility (317)	H	H	M	L	
Vegetative Stabilization					
Pasture & Hayland Planting (512)	H	H	M	L	
Range Seeding (550)	H	H	M	L	
Channel Vegetation (322)	H	H	M	L	
Brush (& Weed) Mgmt (314)	H	H	M	L	
Conservation Cover (327)		H	H	H	
Riparian Buffers (391)		H	H	H	
Critical Area Planting (342)		H	H	H	
Wetland restoration (657)		H	H	H	

Table 11 (cont'd). Example Agricultural Area Management Practice/Hydrologic Flow Zone Considerations

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
CAFO Management					
Waste Management System (312)	H	H	M		
Waste Storage Structure (313)	H	H	M		
Waste Storage Pond (425)	H	H	M		
Waste Treatment Lagoon (359)	H	H	M		
Mulching (484)	H	H	M		
Waste Utilization (633)	H	H	M		
Water & Sediment Control Basin (638)	H	H	M		
Filter Strip (393)	H	H	M		
Sediment Basin (350)	H	H	M		
Grassed Waterway (412)	H	H	M		
Diversion (362)	H	H	M		
Heavy Use Area Protection (561)					
Constructed Wetland (656)					
Dikes (356)	H	H	M		
Lined Waterway or Outlet (468)	H	H	M		
Roof Runoff Mgmt (558)	H	H	M		
Floodwater Diversion (400)	H	H	M		
Terrace (600)	H	H	M		
Potential for source area contribution under given hydrologic condition (H: High; M: Medium; L: Low)					

Note: Numbers in parentheses are the U.S. Soil Conservation Service practice number.

9.5.3 Forestry Source Areas

There are no impaired waterbodies with corresponding HUC-12 subwatersheds or drainage areas classified as source area type predominantly forested, with the predominant source category being wildlife, in the Watauga River watershed.

9.6 Evaluation of TMDL Implementation Effectiveness

Evaluation of the effectiveness of TMDL implementation strategies should be conducted on multiple levels, as appropriate:

- HUC-12 or waterbody drainage area (i.e., TMDL analysis location)
- Subwatersheds or intermediate sampling locations
- Specific landuse areas (urban, pasture, etc.)
- Specific facilities (WWTP, CAFO, uniquely identified portion of MS4, etc.)
- Individual BMPs

In order to conduct an implementation effectiveness analysis on measures to reduce E. coli source loading, monitoring results should be evaluated in one of several ways. Sampling results can be compared to water quality standards (e.g., load duration curve analysis) for determination of impairment status, results can be compared on a before and after basis (temporal), or results can be evaluated both upstream and downstream of source reduction measures or source input (spatial). Considerations include period of record, data collection frequency, representativeness of data, and sampling locations.

In general, periods of record greater than 5 years (given adequate sampling frequency) can be evaluated for determination of relative change (trend analysis). For watersheds in second or successive TMDL cycles, data collected from multiple cycles can be compared. If implementation efforts have been initiated to reduce loading, evaluation of routine monitoring data may indicate improving or worsening conditions over time and corresponding effectiveness of implementation efforts.

Water quality data for implementation effectiveness analysis can be presented in multiple ways. For example, Figure 16 shows best fit curve analyses (regressions) of flow (percent time exceeded) versus E. coli loading, for a historical (1999-2004) period versus a recent post-implementation period of sampling data (2005-2013), for Oostanaula Creek at mile 28.4 (Hiwassee River watershed). The LDCs of the single sample maximum and geometric mean water quality standards are also plotted to illustrate the relative degree of impairment for each period. Figure 17 shows a LDC analysis of E. coli loading statistics for Oostanaula Creek for the same two periods. In addition, the 90th percentiles for each flow zone are plotted for comparison. Lastly, Figure 18 shows E. coli concentration data statistics for recent versus historical data. The individual flow zone analyses are presented in a box and whisker plot of recent [2] versus historical [1] data. Note that Figures 16-18 present the same data, each clearly illustrating improving conditions between historical and recent periods.

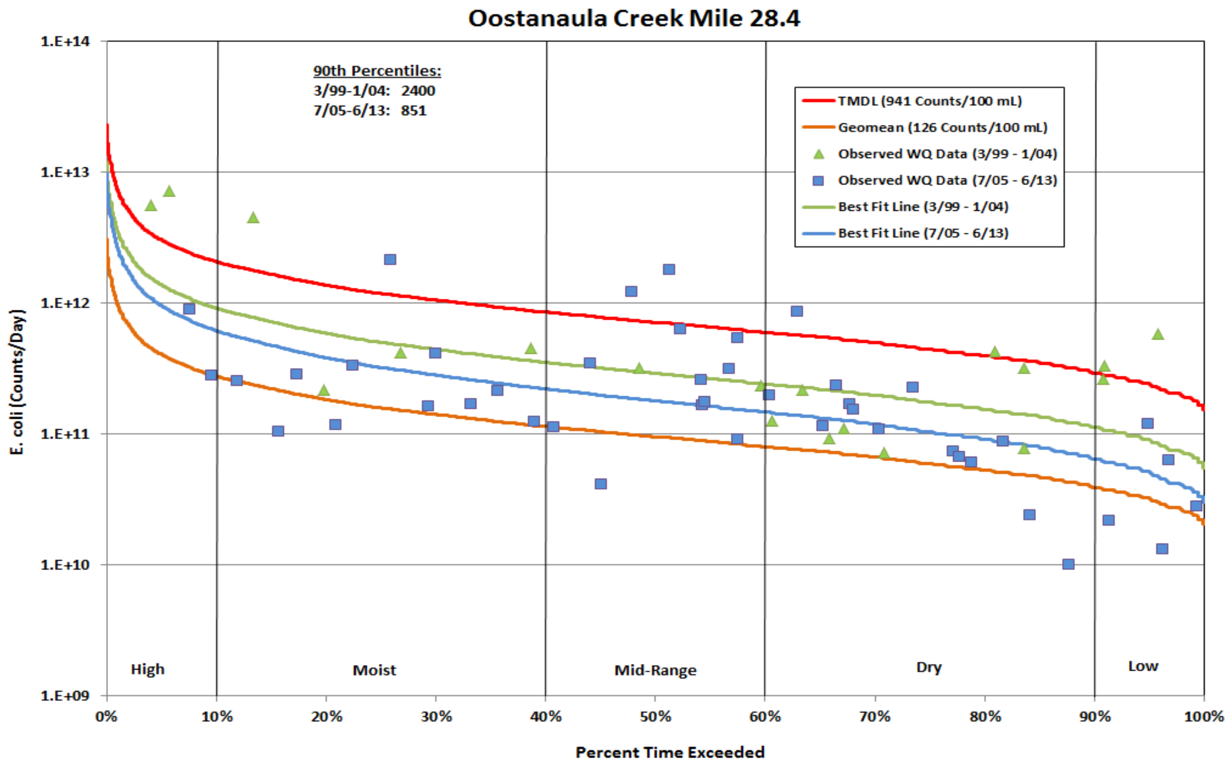

Figure 16. Example Graph of TMDL implementation effectiveness (LDC regression analysis)

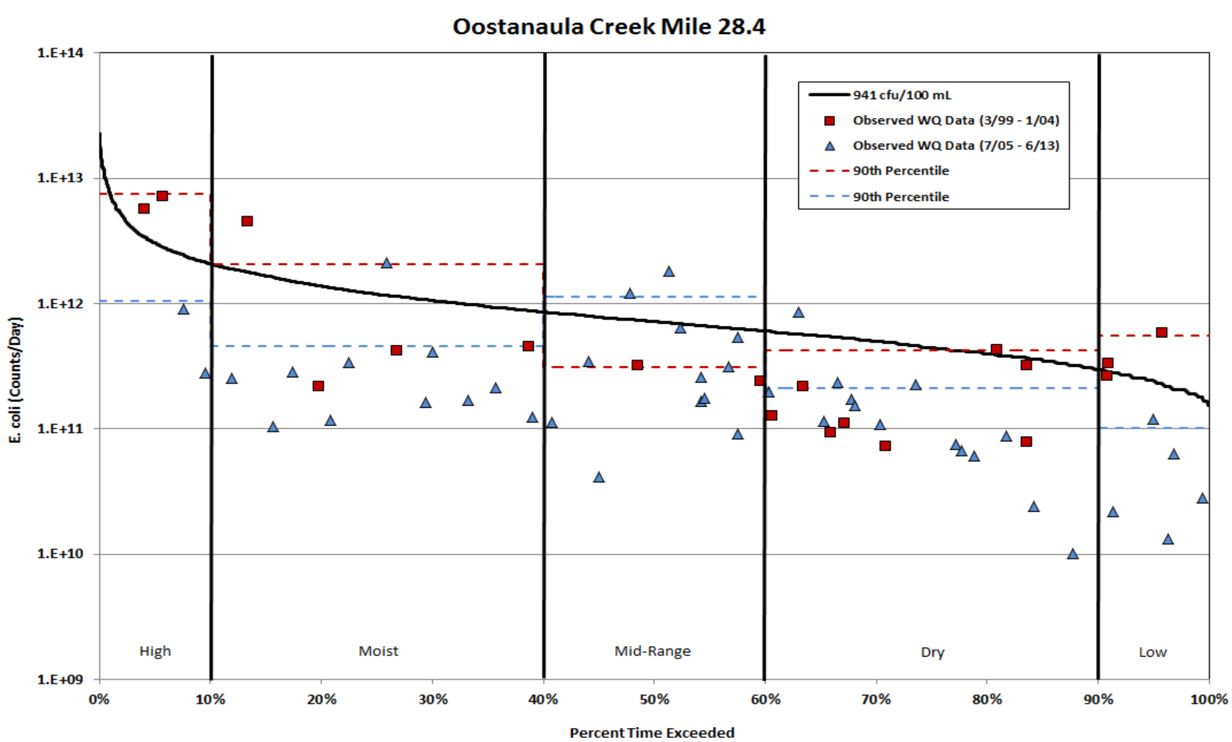

Figure 17. Example Graph of TMDL implementation effectiveness (LDC analysis)

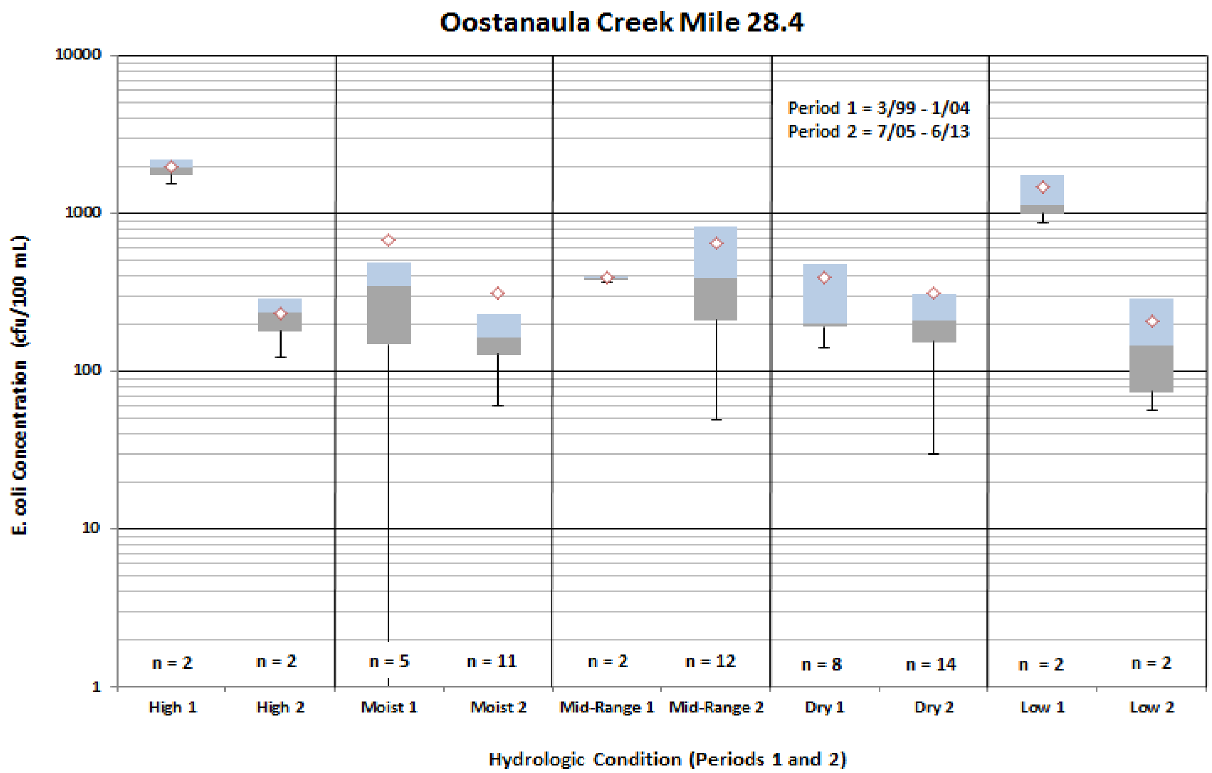

Figure 18. Example Graph of TMDL implementation effectiveness (box and whisker plot)

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed pathogen TMDLs for the Watauga River watershed will be placed on Public Notice for a 35-day period and comments solicited. Steps that will be taken in this regard include:

1) Notice of the proposed TMDLs will be posted on the Tennessee Department of Environment and Conservation website. The announcement will invite public and stakeholder comment and provide a link to a downloadable version of the TMDL document.

2) Notice of the availability of the proposed TMDLs (similar to the website announcement) will be included in one of the NPDES permit Public Notice mailings which is sent to approximately 90 interested persons or groups who have requested this information.

3) Letters will be sent to WWTPs located in E. coli-impaired subwatersheds or drainage areas in the Watauga River watershed, permitted to discharge treated effluent containing pathogens, advising them of the proposed TMDLs and their availability on the TDEC website. The letters will also state that a copy of the draft TMDL document will be provided on request. A letter will be sent to the following facility:

    Mountain City STP (TN0024945)

4) A draft copy of the proposed TMDL will be sent to those MS4s that are wholly or partially located in E. coli-impaired subwatersheds. A draft copy will be sent to the following entities:

    Carter County, Tennessee (TNS075124)
    City of Elizabethton, Tennessee (TNS075281)
    City of Johnson City, Tennessee (TNS075370)
    Sullivan County, Tennessee (TNS075671)
    Tennessee Dept. of Transportation (TNS077585)
    Washington County, Tennessee (TNS075787)

5) A letter will be sent to water quality partners in the Watauga River watershed advising them of the proposed pathogen TMDLs and their availability on the TDEC website. The letter will also state that a written copy of the draft TMDL document will be provided upon request. A letter will be sent to the following partners:

Appalachian RC&D Council
Boone Lake Association
Boone Watershed Partnership, Inc.
Crystal Stream Technologies
Ducks Unlimited
Friends of Roan Mountain
Natural Resources Conservation Service
North Carolina's Basinwide Planning Program
Tennessee Citizens for Wilderness Planning
Tennessee Department of Agriculture – 319 Program
Tennessee Scenic Rivers Association
Tennessee Stream Mitigation Program
Tennessee Valley Authority
Tennessee Wildlife Resources Agency
The Nature Conservancy
Trout Unlimited
US Army Corps of Engineers

11.0 FURTHER INFORMATION

Further information concerning Tennessee's TMDL program can be found on the Internet at the Tennessee Department of Environment and Conservation website:

http://www.tn.gov/environment/water/water-quality_total-daily-maximum-loads.shtml

Technical questions regarding this TMDL should be directed to the following members of the DWR staff:

Vicki Steed, P.E., Watershed Management Section
e-mail: Vicki.Steed@tn.gov

Sherry H. Wang, Ph.D., Fellow, Division of Water Resources
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APPENDIX A

Land Use Distribution in the Watauga River Watershed

Table A-1. 2006 MRLC Land Use Distribution of Impaired HUC-12s & Drainage Areas

Landuse	Impaired Watershed (06010103____) or Waterbody Drainage Area (DA)					
	HUC-12 0101 (Town Ck)		Roan Creek 034-2000 DA		Sink Branch DA (in 0306)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0	0.00	0	0.00	0	0.00
Open Water	0	0.00	4	0.01	0	0.00
Developed, Open Space	1,430	7.58	3,277	5.60	42	4.62
Developed, Low Intensity	251	1.33	345	0.59	0	0.00
Developed, Medium Intensity	123	0.65	135	0.23	0	0.00
Developed, High Intensity	30	0.16	49	0.08	0	0.00
Barren Land (Rock/Sand/Clay)	11	0.06	133	0.23	0	0.00
Deciduous Forest	11,215	59.45	39,388	67.33	664	72.60
Evergreen Forest	1,259	6.68	2,584	4.42	37	4.09
Mixed Forest	696	3.69	1,856	3.17	44	4.77
Shrub/Scrub	92	0.49	425	0.73	0	0.00
Grassland/Herbaceous	158	0.84	648	1.11	9	0.97
Pasture/Hay	3,536	18.75	9,327	15.94	118	12.95
Cultivated Crops	47	0.25	314	0.54	0	0.00
Woody Wetlands	13	0.07	18	0.03	0	0.00
Emergent Herbaceous Wetlands	0	0.00	0	0.00	0	0.00
Subtotal – Urban Impervious	339	1.80	580	0.99	4	0.46
Subtotal – Urban Pervious	1,497	7.94	3,226	5.51	38	4.16
Subtotal – Pasture	3,536	18.75	9,327	15.94	118	12.95
Subtotal - Cropland	47	0.25	314	0.54	0	0.00
Subtotal - Forest	13,444	71.27	45,055	77.02	754	82.43
Total	18,863	100.00	58,501	100.00	915	100.00

Table A-1 (cont'd). 2006 MRLC Land Use Distribution of Impaired HUC-12s & Drainage Areas

Landuse	Impaired Watershed (06010103____) or Waterbody Drainage Area (DA)					
	HUC-12 0502 (Buffalo Ck)		Powder Br DA (in 0502)		Toll Br DA (in 0502)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0	0.00	0	0.00	0	0.00
Open Water	0	0.00	0	0.00	0	0.00
Developed, Open Space	2,855	11.44	459	14.85	129	4.89
Developed, Low Intensity	734	2.94	58	1.89	12	0.47
Developed, Medium Intensity	92	0.37	4	0.12	0	0.00
Developed, High Intensity	19	0.08	0	0.00	0	0.00
Barren Land (Rock/Sand/Clay)	89	0.36	0	0.00	0	0.00
Deciduous Forest	13,752	55.12	1,283	41.54	1,372	52.24
Evergreen Forest	457	1.83	12	0.40	35	1.35
Mixed Forest	617	2.47	6	0.18	81	3.08
Shrub/Scrub	153	0.61	4	0.14	5	0.20
Grassland/Herbaceous	348	1.39	51	1.65	55	2.09
Pasture/Hay	5,805	23.27	1,205	38.99	933	35.52
Cultivated Crops	16	0.06	7	0.24	4	0.15
Woody Wetlands	12	0.05	0	0.00	0	0.00
Emergent Herbaceous Wetlands	0	0.00	0	0.00	0	0.00
Subtotal – Urban Impervious	619	2.48	69	2.22	17	0.65
Subtotal – Urban Pervious	3,081	12.35	452	14.63	124	4.71
Subtotal – Pasture	5,805	23.27	1,205	38.99	933	35.52
Subtotal - Cropland	16	0.06	7	0.24	4	0.15
Subtotal - Forest	15,427	61.84	1,357	43.92	1,549	58.97
Total	24,948	100.00	3,089	100.00	2,627	100.00

Table A-1 (cont'd). 2006 MRLC Land Use Distribution of Impaired HUC-12s & Drainage Areas

Landuse	Impaired Watershed (06010103____) or Waterbody Drainage Area (DA)					
	HUC-12 0503 (Sinking Ck)		HUC-12 0504 (Brush Ck)		Davis Br DA (in 0505)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0	0.00	0	0.00	0	0.00
Open Water	0	0.00	0	0.00	0	0.00
Developed, Open Space	1,655	18.59	2,324	22.24	81	6.10
Developed, Low Intensity	1,074	12.07	2,825	27.03	52	3.89
Developed, Medium Intensity	231	2.59	1,023	9.79	30	2.26
Developed, High Intensity	57	0.64	528	5.05	7	0.55
Barren Land (Rock/Sand/Clay)	1	0.01	1	0.01	2	0.17
Deciduous Forest	3,945	44.30	1,878	17.98	828	62.30
Evergreen Forest	45	0.51	25	0.24	2	0.15
Mixed Forest	114	1.28	34	0.32	14	1.07
Shrub/Scrub	60	0.68	35	0.34	6	0.47
Grassland/Herbaceous	89	1.00	153	1.47	11	0.82
Pasture/Hay	1,631	18.32	1,599	15.30	295	22.22
Cultivated Crops	0	0.00	20	0.19	0	0.02
Woody Wetlands	2	0.02	5	0.05	0	0.00
Emergent Herbaceous Wetlands	0	0.00	0	0.00	0	0.00
Subtotal – Urban Impervious	743	8.34	2,361	22.59	52	3.93
Subtotal – Urban Pervious	2,275	25.54	4,338	41.51	118	8.86
Subtotal – Pasture	1,631	18.32	1,599	15.30	295	22.22
Subtotal - Cropland	0	0.00	20	0.19	0	0.02
Subtotal - Forest	4,256	47.80	2,132	20.40	863	64.97
Total	8,905	100.00	10,450	100.00	1,329	100.00

Table A-1 (cont'd). 2006 MRLC Land Use Distribution of Impaired HUC-12s & Drainage Areas

Landuse	Impaired Watershed (06010103____) or Waterbody Drainage Area (DA)					
	Gap Creek DA (in 0505)		HUC-12 0506 (Knob Ck)		Cobb Creek DA (in 0506)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0	0.00	0	0.00	0	0.00
Open Water	0	0.00	12	0.09	3	0.09
Developed, Open Space	355	5.81	3,162	23.27	889	30.46
Developed, Low Intensity	26	0.43	2,700	19.87	828	28.37
Developed, Medium Intensity	2	0.03	1,054	7.76	306	10.50
Developed, High Intensity	0	0.00	465	3.42	138	4.74
Barren Land (Rock/Sand/Clay)	16	0.26	4	0.03	0	0.00
Deciduous Forest	4,177	68.41	2,882	21.21	485	16.63
Evergreen Forest	81	1.32	63	0.46	25	0.86
Mixed Forest	38	0.62	39	0.29	14	0.48
Shrub/Scrub	29	0.48	36	0.26	16	0.53
Grassland/Herbaceous	71	1.16	166	1.22	32	1.11
Pasture/Hay	1,308	21.42	2,994	22.04	176	6.03
Cultivated Crops	4	0.07	10	0.07	4	0.15
Woody Wetlands	0	0.00	2	0.01	2	0.05
Emergent Herbaceous Wetlands	0	0.00	0	0.00	0	0.00
Subtotal – Urban Impervious	46	0.75	2,365	17.40	702	24.07
Subtotal – Urban Pervious	337	5.52	5,016	36.91	1,459	50.00
Subtotal – Pasture	1,308	21.42	2,994	22.04	176	6.03
Subtotal - Cropland	4	0.07	10	0.07	4	0.15
Subtotal - Forest	4,411	72.24	3,204	23.57	577	19.75
Total	6,106	100.00	13,589	100.00	2,918	100.00

Table A-1 (cont'd). 2006 MRLC Land Use Distribution of Impaired HUC-12s & Drainage Areas

Landuse	Impaired Watershed (06010103____) or Waterbody Drainage Area (DA)					
	Cash Hollow Ck DA (in 0506)		HUC-12 0507 (Boones Ck)		Carroll Creek DA (in 0507)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0	0.00	0	0.00	0	0.00
Open Water	0	0.00	20	0.18	0	0.00
Developed, Open Space	365	20.21	1,481	13.33	344	18.19
Developed, Low Intensity	188	10.39	1,188	10.69	412	21.81
Developed, Medium Intensity	23	1.29	215	1.93	54	2.88
Developed, High Intensity	0	0.01	30	0.27	5	0.29
Barren Land (Rock/Sand/Clay)	1	0.07	9	0.08	0	0.00
Deciduous Forest	968	53.53	1,932	17.38	338	17.87
Evergreen Forest	3	0.17	14	0.13	0	0.00
Mixed Forest	5	0.29	25	0.22	6	0.33
Shrub/Scrub	4	0.23	15	0.14	1	0.07
Grassland/Herbaceous	46	2.55	119	1.07	12	0.63
Pasture/Hay	203	11.24	5,959	53.61	686	36.31
Cultivated Crops	0	0.01	107	0.96	31	1.62
Woody Wetlands	0	0.00	0	0.00	0	0.00
Emergent Herbaceous Wetlands	0	0.00	0	0.00	0	0.00
Subtotal – Urban Impervious	118	6.51	730	6.57	219	11.58
Subtotal – Urban Pervious	459	25.40	2,184	19.65	597	31.58
Subtotal – Pasture	203	11.24	5,959	53.61	686	36.31
Subtotal - Cropland	0	0.01	107	0.96	31	1.62
Subtotal - Forest	1,027	56.84	2,135	19.21	357	18.90
Total	1,808	100.00	11,115	100.0	1,889	100.0

Table A-1 (cont'd). 2006 MRLC Land Use Distribution of Impaired HUC-12s & Drainage Areas

Landuse	Impaired Watershed (06010103____) or Waterbody Drainage Area (DA)			
	Darr Creek DA (in 0508)		Reedy Creek DA (in 0508)	
	[acres]	[%]	[acres]	[%]
Unclassified	0	0.00	0	0.00
Open Water	33	1.71	2	0.04
Developed, Open Space	75	3.86	295	8.37
Developed, Low Intensity	3	0.16	180	5.09
Developed, Medium Intensity	0	0.00	3	0.09
Developed, High Intensity	0	0.00	4	0.12
Barren Land (Rock/Sand/Clay)	3	0.17	1	0.04
Deciduous Forest	814	41.84	981	27.84
Evergreen Forest	19	0.98	15	0.42
Mixed Forest	8	0.42	6	0.18
Shrub/Scrub	6	0.32	2	0.07
Grassland/Herbaceous	26	1.36	60	1.70
Pasture/Hay	924	47.52	1,882	53.38
Cultivated Crops	32	1.65	93	2.65
Woody Wetlands	0	0.00	0	0.00
Emergent Herbaceous Wetlands	0	0.00	0	0.00
Subtotal – Urban Impervious	9	0.44	98	2.79
Subtotal – Urban Pervious	70	3.58	384	10.89
Subtotal – Pasture	924	47.52	1,882	53.38
Subtotal - Cropland	32	1.65	93	2.65
Subtotal - Forest	910	46.81	1,068	30.29
Total	1,944	100.0	3,526	100.0

APPENDIX B

Water Quality Monitoring Data for the Watauga River Watershed

There are a number of water quality monitoring stations that provide data for waterbodies identified as impaired for pathogens in the Watauga River watershed. The location of these monitoring stations is shown in Figure 5. Monitoring data recorded by TDEC at these stations are tabulated in Table B-1.

Table B-1. TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
BOONE000.7WN	7/12/06	2280
	7/27/06	1340
	8/1/06	1203
	8/8/06	291
	8/22/06	1120
	9/6/06	2419
	9/12/06	1733
	9/26/06	613
	10/11/06	435
	10/18/06	1300
	11/7/06	435
	12/6/06	1046
	1/10/07	461
	1/17/07	214
	2/6/07	82
	3/7/07	238
	4/4/07	1986
	4/11/07	1414
	5/1/07	5570
	7/14/11	7800
	8/23/11	1300
	9/7/11	1986
	9/14/11	579
	9/21/11	1203
	9/28/11	816
	10/5/11	1120
	11/2/11	201
	1/17/12	308
	3/20/12	1203
	5/15/12	46110
	6/12/12	2420

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
BOONE001.7WN	7/12/06	517
	8/1/06	365
	9/6/06	1986
	10/11/06	326
	11/7/06	770
	12/6/06	488
	1/10/07	387
	2/6/07	127
	3/7/07	98
	4/4/07	980
	5/1/07	201
	6/5/07	1553
	7/14/11	1203
	8/23/11	214
	9/7/11	1733
	9/14/11	1986
	9/21/11	921
	9/28/11	816
	10/5/11	166
	11/2/11	276
	1/17/12	201
	3/20/12	980
	5/15/12	32550
	6/12/12	>2420
BOONE003.7WN	7/12/06	649
	8/1/06	649
	9/6/06	3310
	10/11/06	1553
	11/7/06	1733
	12/6/06	3310
	1/10/07	488
	3/7/07	194
	4/4/07	30760
	5/1/07	687
	6/5/07	4390
	7/14/11	8600
	8/23/11	1414

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
BOONE003.7WN (cont'd)	9/7/11	3280
	9/14/11	1986
	9/21/11	2420
	9/28/11	727
	10/5/11	2420
	11/2/11	2420
	1/17/12	1046
	3/20/12	>2420
	5/15/12	38730
	6/12/12	>2420
BOONE007.6WN	7/12/06	3930
	8/1/06	2419
	9/6/06	1986
	10/11/06	10140
	11/7/06	1733
	12/6/06	980
	1/10/07	5040
	2/6/07	1046
	3/7/07	9330
	4/4/07	64880
	4/18/07	6540
	4/24/07	11620
	5/1/07	5910
	5/2/07	2419
	5/9/07	2419
	6/5/07	12960
	6/6/07	7330
	6/20/07	4190
	7/14/11	2420
	8/23/11	1300
	9/7/11	2420
	9/14/11	3230
	9/21/11	1553
	9/28/11	1414
	10/5/11	12110
	11/2/11	649

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
BOONE007.6WN (cont'd)	1/17/12	1120
	3/20/12	4200
	5/15/12	9330
	6/12/12	2880
BRUSH000.7WN	7/19/06	345
	7/27/06	740
	8/8/06	4410
	8/22/06	548
	9/12/06	1414
	9/26/06	548
	10/18/06	770
	10/31/06	172
	11/20/06	387
	1/17/07	326
	1/24/07	1300
	2/20/07	104
	3/13/07	210
	3/27/07	43
	4/11/07	194
	7/12/11	5370
	8/17/11	326
	9/1/11	272
	9/8/11	488
	9/15/11	387
	9/22/11	276
	9/29/11	411
	11/9/11	162
	1/10/12	261
	3/6/12	326
	5/8/12	411
	6/6/12	107
BRUSH006.1WN	5/29/12	82
	5/31/12	23
	6/6/12	44
	6/12/12	96
	6/14/12	61
	6/20/12	27

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
BUFFA000.2CT	7/19/06	770
	9/20/06	345
	11/20/06	488
	2/20/07	70
	4/11/07	111
	4/18/07	345
	4/24/07	345
	5/2/07	365
	5/9/07	727
	6/6/07	328
	7/19/11	411
	8/24/11	206
	9/1/11	387
	9/8/11	308
	9/15/11	365
	9/22/11	411
	9/29/11	190
	11/1/11	70
	1/11/12	93
	3/7/12	66
	5/9/12	2920
	6/6/12	365
BUFFA005.5CT	7/19/06	8390
	9/20/06	6500
	11/20/06	1553
	2/20/07	436
	4/11/07	27
	4/18/07	1120
	4/24/07	387
	5/2/07	1732
	5/9/07	1203
	6/6/07	1733
BUFFA006.3CT	7/19/06	93
	9/20/06	71
	11/20/06	127

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
BUFFA006.3CT (cont'd)	2/20/07	32
	4/11/07	35
	4/18/07	139
	4/24/07	65
	5/2/07	166
	5/9/07	285
	6/6/07	345
CARRO000.5WN	7/14/11	613
	8/23/11	140
	9/7/11	411
	9/14/11	308
	9/21/11	261
	9/28/11	179
	10/5/11	127
	11/2/11	49
	1/17/12	411
	3/20/12	921
	5/15/12	866
	6/12/12	2420
CARRO000.7WN	7/12/06	517
	7/27/06	687
	8/1/06	727
	8/8/06	980
	8/22/06	980
	9/6/06	816
	9/12/06	168
	9/26/06	548
	10/11/06	1046
	10/18/06	1553
	11/7/06	365
	12/6/06	272
	1/10/07	225
	1/17/07	130
	2/6/07	411
	3/7/07	196

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
CARRO000.7WN (cont'd)	4/4/07	2419
	4/11/07	3180
	4/18/07	281
	4/24/07	387
	5/1/07	649
	5/9/07	488
CASH_G0.3WN	9/9/99	159
	3/7/00	185
	3/9/00	162
	3/14/00	222
	3/16/00	2419
	3/21/00	579
	3/23/00	114
	3/28/00	114
	3/29/00	613
	4/3/00	1553
	4/4/00	687
	7/14/11	114
	8/23/11	387
	9/7/11	1733
	9/14/11	1733
	9/21/11	411
	9/28/11	411
	10/5/11	9330
	11/2/11	>2420
	1/17/12	291
	3/20/12	365
	5/15/12	127
	6/12/12	3790
CASH_G2.7WN	9/9/99	613
	3/7/00	50
	3/9/00	46
	3/14/00	50
	3/16/00	55
	3/21/00	157
	3/23/00	38
	3/28/00	185

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
CASH_G2.7WN (cont'd)	3/30/00	387
	4/3/00	727
	4/4/00	1300
	7/14/11	548
	8/23/11	613
	9/7/11	488
	9/14/11	308
	9/21/11	345
	9/28/11	206
	10/5/11	276
	11/2/11	261
	1/17/12	228
	3/20/12	66
	6/12/12	770
	6/15/12	248
COBB000.1WN	7/12/06	687
	8/1/06	29
	9/6/06	461
	10/11/06	613
	11/7/06	138
	12/6/06	18
	2/6/07	205
	7/14/11	260
	8/23/11	157
	9/7/11	1203
	9/14/11	326
	9/21/11	261
	9/28/11	649
	10/5/11	488
	11/2/11	153
	1/17/12	146
	3/20/12	65
	5/15/12	365
	6/12/12	1300
COBB001.0WN	7/14/11	326
	8/23/11	166
	9/7/11	1414

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
COBB001.0WN (cont'd)	9/14/11	105
	9/21/11	105
	9/28/11	365
	10/5/11	225
	11/2/11	124
	1/17/12	148
	3/20/12	71
	5/15/12	579
	6/12/12	2420
DARR001.2SU	7/14/11	6850
	8/23/11	649
	9/7/11	687
	9/14/11	291
	9/21/11	1414
	9/28/11	1733
	10/5/11	921
	11/2/11	187
	1/17/12	138
	3/20/12	194
	5/15/12	1046
	6/12/12	2420
DAVIS000.9CT	7/19/06	102
	7/27/06	19
	8/8/06	118
	8/22/06	40
	9/12/06	921
	9/26/06	248
	10/18/06	411
	10/31/06	71
	11/20/06	1414
	1/17/07	1203
	1/24/07	147
	2/20/07	5
	3/13/07	411
	3/27/07	42
	4/11/07	397
	7/19/11	80
	8/24/11	435

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
DAVIS000.9CT (cont'd)	9/1/11	411
	9/8/11	517
	9/15/11	299
	9/22/11	236
	9/29/11	328
	11/1/11	17
	1/11/12	1203
	3/7/12	285
	5/9/12	2420
	6/6/12	108
	6/5/13	385
GAP000.1CT	7/25/07	2590
	9/19/07	150
	9/25/07	238
	10/3/07	99
	10/9/07	488
	10/11/07	365
	7/19/11	579
	8/24/11	2420
	9/1/11	1986
	9/8/11	1986
	9/15/11	5460
	9/22/11	1300
	9/29/11	548
	11/1/11	727
	1/11/12	727
	3/7/12	201
	5/9/12	4040
	6/6/12	1046
GAP000.4CT	7/19/06	1120
	7/27/06	980
	8/8/06	1986
	8/22/06	517
	9/12/06	613
	9/26/06	770
	10/18/06	488
	10/31/06	291

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
GAP000.4CT (cont'd)	11/20/06	130
	1/17/07	29
	1/24/07	131
	2/20/07	59
	3/13/07	144
	3/27/07	26
	4/11/07	131
KNOB001.0WN	7/12/06	517
	7/27/06	410
	8/1/06	121
	8/8/06	1986
	8/22/06	517
	9/6/06	326
	9/12/06	687
	9/26/06	400
	10/11/06	276
	10/18/06	687
	11/7/06	345
	12/6/06	157
	1/10/07	144
	2/6/07	153
	3/7/07	24
	4/4/07	1733
	4/11/07	411
	5/1/07	186
	8/23/11	980
	9/7/11	1553
	9/14/11	488
	9/21/11	613
	9/28/11	411
	10/5/11	435
	11/2/11	133
	1/17/12	816
	3/20/12	649
	5/15/12	1733
	6/12/12	4140

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
KNOB003.7WN	7/12/06	488
	8/1/06	921
	9/6/06	866
	10/11/06	461
	11/7/06	345
	12/6/06	135
	1/10/07	126
	2/6/07	365
	3/7/07	91
	4/4/07	5040
	5/1/07	579
	6/5/07	2419
	7/14/11	>2420
	8/23/11	1300
	9/7/11	687
	9/14/11	613
	9/21/11	548
	9/28/11	613
	10/5/11	461
	11/2/11	120
	1/17/12	74
	3/20/12	435
	5/15/12	1733
	6/12/12	20640
KNOB005.8WN	7/12/06	365
	8/1/06	36540
	9/6/06	1120
	10/11/06	770
	11/7/06	770
	12/6/06	387
	1/20/07	548
	2/6/07	411
	3/7/07	238
	4/4/07	26020
	4/18/07	921
	4/24/07	1046

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
KNOB005.8WN (cont'd)	5/1/07	2650
	5/2/07	1553
	5/9/07	2419
	6/5/07	649
	6/6/07	649
	6/20/07	2430
	7/14/11	687
	8/23/11	411
	9/7/11	866
	9/14/11	770
	9/21/11	3270
	9/28/11	816
	10/5/11	488
	11/2/11	435
	1/17/12	86
	3/20/12	387
	5/15/12	1046
	6/12/12	2024
KNOB007.1WN	7/12/06	5370
	8/1/06	1986
	9/6/06	2914
	10/11/06	1203
	11/7/06	727
	12/6/06	1553
	1/10/07	921
	2/6/07	3890
	3/7/07	1733
	4/4/07	17220
	5/1/07	1300
	6/5/07	980
	7/14/11	1986
	8/23/11	1414
	9/7/11	2420
	9/14/11	>2420
	9/21/11	>2420
	9/28/11	816

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
KNOB007.1WN (cont'd)	10/5/11	4410
	11/2/11	387
	1/17/12	236
	3/20/12	1300
	5/15/12	1553
	6/12/12	1733
POWDE000.4CT	7/19/11	1300
	8/24/11	7940
	9/1/11	517
	9/8/11	613
	9/15/11	411
	9/22/11	488
	9/29/11	816
	11/1/11	613
	1/11/12	104
	3/7/12	50
	5/9/12	3590
	6/6/12	727
REEDY001.8WN	7/12/06	3590
	7/27/06	1850
	8/1/06	2720
	8/8/06	5210
	8/22/06	1733
	9/6/06	921
	9/12/06	649
	9/26/06	68670
	10/11/06	4650
	10/18/06	1120
	11/7/06	1773
	12/6/06	272
	1/10/07	91
	1/17/07	80
	2/6/07	687
	3/7/07	2419
	4/4/07	3090
	4/11/07	2419
	4/18/07	1553
	4/24/07	1986

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
REEDY001.8WN (cont'd)	5/1/07	1414
	5/9/07	1733
	7/14/11	649
	8/23/11	387
	9/7/11	649
	9/14/11	687
	9/21/11	435
	9/28/11	291
	10/5/11	119
	11/2/11	184
	1/17/12	141
	3/20/12	1414
	5/15/12	1986
	6/12/12	816
ROAN011.8JO	7/18/01	740
	8/8/01	410
	9/5/01	410
	10/10/01	100
	11/7/01	200
	12/5/01	200
	1/16/02	100
	2/6/02	100
	3/13/02	100
	4/23/02	410
	5/8/02	630
	6/11/02	1220
	7/17/06	8
	11/14/06	10
	2/7/07	2
	5/8/07	82
	7/21/11	141
	8/30/11	291
	9/13/11	71
	9/20/11	173
	9/27/11	344
	10/4/11	89
	10/11/11	365
	11/8/11	11

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
ROAN011.8JO (cont'd)	1/19/12	<1
	3/21/12	11
	5/22/12	24
	6/20/12	2
ROAN016.6JO	2/27/01	10
	5/15/01	135
	7/18/01	2590
	8/8/01	1100
	9/5/01	310
	10/10/01	200
	11/7/01	200
	12/5/01	1990
	1/16/02	100
	2/6/02	410
	3/13/02	3790
	4/23/02	980
	5/8/02	1580
	6/11/02	3160
	7/17/06	7
	11/14/06	3
	2/7/07	2
	5/8/07	242
	7/21/11	206
	8/30/11	9340
	9/13/11	96
	9/20/11	29
	9/27/11	15530
	10/4/11	284
	10/11/11	549
	11/8/11	7
	1/19/12	3
	3/21/12	39
	5/22/12	23
	6/20/12	437
ROAN018.2JO	2/27/01	1
	5/15/01	436
	7/18/01	860

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
ROAN018.2JO (cont'd)	8/8/01	1100
	9/5/01	410
	10/10/01	100
	11/7/01	<100
	12/5/01	<100
	1/16/02	<100
	2/6/02	100
	3/13/02	310
	4/23/02	300
	5/8/02	<100
	6/11/02	520
	7/21/11	119
	8/30/11	36
	9/13/11	15
	9/20/11	55
	9/27/11	37
	10/4/11	6
	10/11/11	47
	11/8/11	3
	1/19/12	<1
	3/21/12	1
	5/22/12	11
	6/20/12	7
SINK000.7JO	7/17/06	2419
	7/27/06	30760
	8/8/06	8330
	8/22/06	2419
	9/12/06	1414
	9/26/06	517
	10/18/06	1203
	10/31/06	238
	11/14/06	37
	1/17/07	4
	1/24/07	1
	2/7/07	37
	3/13/07	5940
	3/27/07	2
	4/10/07	173

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
SINK000.7JO (cont'd)	4/17/07	134
	4/23/07	20140
	4/30/07	50
	5/8/07	173
	7/21/11	921
	8/30/11	167
	9/13/11	8570
	9/20/11	6770
	9/27/11	579
	10/4/11	10860
	10/11/11	23820
	11/8/11	1986
	1/19/12	2420
	3/21/12	27
	5/22/12	87
	6/20/12	2850
SINKI000.6CT	9/9/99	579
	3/7/00	130
	3/9/00	80
	3/14/00	192
	3/16/00	102
	3/21/00	210
	3/23/00	44
	3/28/00	115
	3/30/00	147
	4/3/00	1553
	4/4/00	2419
	7/19/11	326
	8/24/11	210
	9/1/11	236
	9/8/11	488
	9/15/11	249
	9/22/11	186
	9/29/11	133
	11/1/11	71
	1/11/12	435
	3/7/12	142

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
SINKI000.6CT (cont'd)	5/9/12	4320
	6/6/12	980
TOLL000.3CT	7/19/11	5120
	8/24/11	48840
	9/1/11	36540
	9/8/11	3230
	9/15/11	29090
	9/22/11	>241960
	9/29/11	>241960
	11/1/11	1203
	1/11/12	770
	3/7/12	517
	5/9/12	2420
	6/6/12	187
TOLL001.5CT	1/11/12	299
	3/7/12	214
	5/9/12	201
	6/6/12	299
TOLL002.5CT	3/7/12	62
	5/9/12	14
	6/6/12	435
	1/11/13	1
TOWN000.3JO	7/17/06	13
	11/14/06	2
	2/7/07	19
	5/8/07	25
	7/21/11	148
	8/30/11	59
	9/13/11	66
	9/20/11	345
	9/27/11	649
	10/4/11	816
	10/11/11	96
	11/8/11	14
	1/19/12	<1
	3/21/12	47
	5/22/12	119
	6/20/12	326

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100mL]
TOWN000.9JO	7/17/06	6
	7/27/06	12
	8/8/06	16
	8/22/06	5
	9/12/06	10
	9/26/06	13
	10/18/06	25
	10/31/06	7
	11/14/06	1
	1/17/07	1
	1/24/07	1
	2/7/07	1
	3/13/07	1
	3/27/07	9
	4/10/07	3
	4/17/07	13
	4/23/07	50
	4/30/07	5
	5/8/07	12
	7/21/11	687
	8/30/11	48
	9/13/11	39
	9/20/11	435
	9/27/11	162
	10/4/11	1553
	10/11/11	167
	11/8/11	17
	1/19/12	1
	3/21/12	40
	5/22/12	75
	6/20/12	313

APPENDIX C

Load Duration Curve Development
and
Determination of Daily Loading

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), nonpoint type source loads (Load Allocations), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) (http://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol22/pdf/CFR-2011-title40-vol22-sec130-2.pdf) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

C.1 Development of TMDLs

E. coli TMDLs, WLAs, and LAs were developed for impaired subwatersheds and drainage areas in the Watauga River watershed using Load Duration Curves (LDCs). Daily loads for TMDLs, WLAs, and LAs are expressed as a function of daily mean in-stream flow (daily loading function).

C.1.1 Development of Flow Duration Curves

A flow duration curve is a cumulative frequency graph, constructed from historic flow data at a particular location, that represents the percentage of time a particular flow rate is equaled or exceeded. Flow duration curves are developed for a waterbody from daily discharges of flow over an extended period of record. In general, there is a higher level of confidence that curves derived from data over a long period of record accurately represent the entire range of flow. The preferred method of flow duration curve computation uses daily mean data from USGS continuous-record stations (http://waterdata.usgs.gov/tn/nwis/sw) located on the waterbody of interest. For ungaged streams, alternative methods must be used to estimate daily mean flow. These include: 1) regression equations (using drainage area as the independent variable) developed from continuous record stations in the same ecoregion; 2) drainage area extrapolation of data from a nearby continuous-record station of similar size and topography; and 3) calculation of daily mean flow using a dynamic computer model, such as the Windows version of Hydrologic Simulation Program - Fortran (WinHSPF).

Flow duration curves for impaired waterbodies in the Watauga River watershed were derived from WinHSPF hydrologic simulations based on parameters derived from calibrations at several USGS gaging stations (see Appendix D for details of calibration). For example, a flow duration curve for Roan Creek was constructed using simulated daily mean flow for the period from 10/1/02 through 9/30/12 (RM 16.6 corresponds to the location of monitoring stations ROAN016.6JO). This flow duration curve is shown in Figure C-1 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record (the highest daily mean flow during this period is exceeded 0% of the time and the lowest daily mean flow is equaled or exceeded 100% of the time). Flow duration curves for other impaired waterbodies were derived using a similar procedure.

C.1.2 Development of Load Duration Curves and TMDLs

When a water quality target concentration is applied to the flow duration curve, the resulting load duration curve (LDC) represents the allowable pollutant loading in a waterbody over the entire range of flow. Pollutant monitoring data, plotted on the LDC, provides a visual depiction of stream water quality as well as the frequency and magnitude of any exceedances. Load duration curve intervals can be grouped into several broad categories or zones, in order to provide additional insight about conditions and patterns associated with the impairment. For example, the duration curve could be divided into five zones: high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-60%), dry conditions (60-90%), and low flows (90-100%). Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left on the LDC (representing zones of higher flow) generally reflect potential nonpoint type source contributions (Stiles, 2003).

E. coli load duration curves for impaired waterbodies in the Watauga River watershed were developed from the flow duration curves developed in Section C.1.1, E. coli target concentrations, and available water quality monitoring data. Load duration curves and required load reductions were developed using the following procedure (Roan Creek at RM16.6 is shown as an example):

1. A target load duration curve (LDC) was generated for Roan Creek by applying the E. coli target concentration of 487 CFU/100 mL to each of the ranked flows used to generate the flow duration curve (ref.: Section D.1) and plotting the results. The E. coli target maximum load corresponding to each ranked daily mean flow is:

   $(\text{Target Load})_{\text{Roan Creek}}$ = (487 CFU/100 mL) x (Q) x (UCF)

   where: Target Load = TMDL (CFU/day)
   Q = daily instream mean flow (cfs)
   UCF = the required unit conversion factor

   TMDL = (1.20×10^{10}) x (Q) CFU/day

2. Daily loads were calculated for each of the water quality samples collected at monitoring station ROANO016.6JO (ref.: Table B-1) by multiplying the sample concentration by the daily mean flow for the sampling date and the required unit conversion factor.

   Note: *In order to be consistent for all analyses, the derived daily mean flow was used to compute sampling data loads, even if measured ("instantaneous") flow data were available for some sampling dates.*

   Example – 11/8/11 sampling event
   Modelled Flow = 74.35 cfs
   Concentration = 7 CFU/100 mL
   Daily Load = 1.27×10^{10} CFU/day

3. Using the flow duration curves developed in C.1.1, the "percent of days the flow was exceeded" (PDFE) was determined for each sampling event. Each sample load was then plotted on the load duration curves developed in Step 1 according to the PDFE. The resulting E. coli load duration curve for Roan Creek is shown in Figure C-2.

LDCs of other impaired waterbodies were derived in a similar manner and are shown in Appendix E.

C.2 Development of WLAs & LAs

As previously discussed, a TMDL can be expressed as the sum of all point source loads (WLAs), nonpoint type source loads (LAs), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

Expanding the terms:

$$\text{TMDL} = [\Sigma \text{WLAs}]_{\text{WWTP}} + [\Sigma \text{WLAs}]_{\text{MS4}} + [\Sigma \text{WLAs}]_{\text{CAFO}} + [\Sigma \text{LAs}]_{\text{DS}} + [\Sigma \text{LAs}]_{\text{SW}} + \text{MOS}$$

For E. coli TMDLs in each impaired subwatershed or drainage area, WLA terms include:

- $[\Sigma \text{WLAs}]_{\text{WWTP}}$ is the allowable load associated with discharges of NPDES permitted WWTPs located in impaired subwatersheds or drainage areas. Since NPDES permits for these facilities specify that treated wastewater must meet in-stream water quality standards at the point of discharge, no additional load reduction is required. WLAs for WWTPs are calculated from the mean daily facility flow (expressed as "q_m") and the Daily Maximum permit limit.
- $[\Sigma \text{WLAs}]_{\text{CAFO}}$ is the allowable load for all CAFOs in an impaired subwatershed or drainage area. All wastewater discharges from a CAFO to waters of the state of Tennessee are prohibited, except when either chronic or catastrophic rainfall events cause an overflow of process wastewater from a facility properly designed, constructed, maintained, and operated to contain:
    - All process wastewater resulting from the operation of the CAFO (such as wash water, parlor water, watering system overflow, etc.); plus,
    - All runoff from a 25-year, 24-hour rainfall event for the existing CAFO or new dairy or cattle CAFOs; or all runoff from a 100-year, 24-hour rainfall event for a new swine or poultry CAFO.

  Therefore, a WLA of zero has been assigned to this class of facilities.
- $[\Sigma \text{WLAs}]_{\text{MS4}}$ is the allowable E. coli load for discharges from MS4s. E. coli loading from MS4s is the result of buildup/wash-off processes associated with storm events.

LA terms include:

- $[\Sigma \text{LAs}]_{\text{DS}}$ is the allowable E. coli load from "other direct sources". These sources include leaking septic systems, illicit discharges, and animals access to streams. The LA specified for all sources of this type is zero CFU/day (or to the maximum extent feasible).
- $[\Sigma \text{LAs}]_{\text{SW}}$ represents the allowable E. coli loading from nonpoint type sources indirectly going to surface waters from all land use areas (except areas covered by a MS4 permit)

as a result of the buildup/wash-off processes associated with storm events (i.e., precipitation induced).

Since $[\sum WLAs]_{CAFO} = 0$ and $[\sum LAs]_{DS} = 0$, the expression relating TMDLs to precipitation-based point and nonpoint type sources may be simplified to:

$$TMDL - MOS = [WLAs]_{WWTP} + [\sum WLAs]_{MS4} + [\sum LAs]_{SW}$$

As stated in Section 8.5, an explicit MOS, equal to 10% of the E. coli water quality targets (ref.: Section 5.0), was utilized for determination of the percent load reductions necessary to achieve WLAs and LAs:

Instantaneous Maximum (lake, reservoir, State Scenic River, Exceptional Tennessee Waters):

Target – MOS = (487 CFU/100 ml) – 0.1(487 CFU/100 ml)

Target – MOS = 438 CFU/100 ml

Instantaneous Maximum (other):

Target – MOS = (941 CFU/100 ml) – 0.1(941 CFU/100 ml)

Target – MOS = 847 CFU/100 ml

30-Day Geometric Mean: Target – MOS = (126 CFU/100 ml) – 0.1(126 CFU/100 ml)

Target – MOS = 113 CFU/100 ml

C.2.1 Daily Load Calculation

Since WWTPs discharge must comply with instream water quality criteria (TMDL target) at the point of discharge, WLAs for WWTPs are expressed as a function of the mean daily facility flow (“q_m”) and the Daily Maximum permit limit. In addition, WLAs for MS4s and LAs for precipitation-based nonpoint type sources are equal on a per unit area basis and may be expressed as the daily allowable load per unit area (acre) resulting from a decrease in in-stream E. coli concentrations to TMDL target values minus MOS:

$$WLA[MS4] = LA = \{TMDL - MOS - WLA[WWTPs]\} / DA$$

where: DA = waterbody drainage area (acres)

Using Roan Creek as an example:

$TMDL_{Roan\ Creek}$ = (487 CFU/100 mL) x (Q) x (UCF)

$$\mathbf{TMDL = 1.20x10^{10} \times Q}$$

$MOS_{Roan\ Creek}$ = TMDL x 0.10 = 1.20×10^9 x Q

MOS = (1.20×10^9) x (Q) CFU/day

$WLA[WWTPs]_{Roan\ Creek}$ = 487 (CFU/100 mL) x q_m (cfs) x UCF

$WLA[WWTPs]_{Roan\ Creek}$ = (1.20×10^{10}) x (q_m) CFU/day

Therefore, since mean daily facility flow can be as high as design flow (q_d), conservatively:

$WLA[MS4]_{Roan\ Creek}$ = $LA_{Roan\ Creek}$

= {TMDL – MOS – $WLA[WWTPs]_{max}$} / DA

= {(1.20×10^{10} x Q) – (1.20×10^9 x Q) – (1.20×10^{10} x q_d)} / (58,501)

$WLA[MS4]_{Roan\ Creek}$ = $LA_{Roan\ Creek}$ = [1.846×10^5 x Q] – [2.448×10^5]

For cases in which there is no WWTP currently discharging to the waterbody, the variable q_d will be retained in the equation as a placeholder for any future WWTPs. Using Buffalo Creek as an example:

$WLA[MS4]_{Buffalo\ Creek}$ = $LA_{Buffalo\ Creek}$

= {(2.30×10^{10} x Q) – (2.30×10^9 x Q) – (2.30×10^{10} x q_d)} / (24,948)

= [8.297×10^5 x Q] – [9.239×10^5 x q_d]

TMDLs, WLAs, & LAs for other impaired subwatersheds and drainage areas were derived in a similar manner and are summarized in Table C-1.

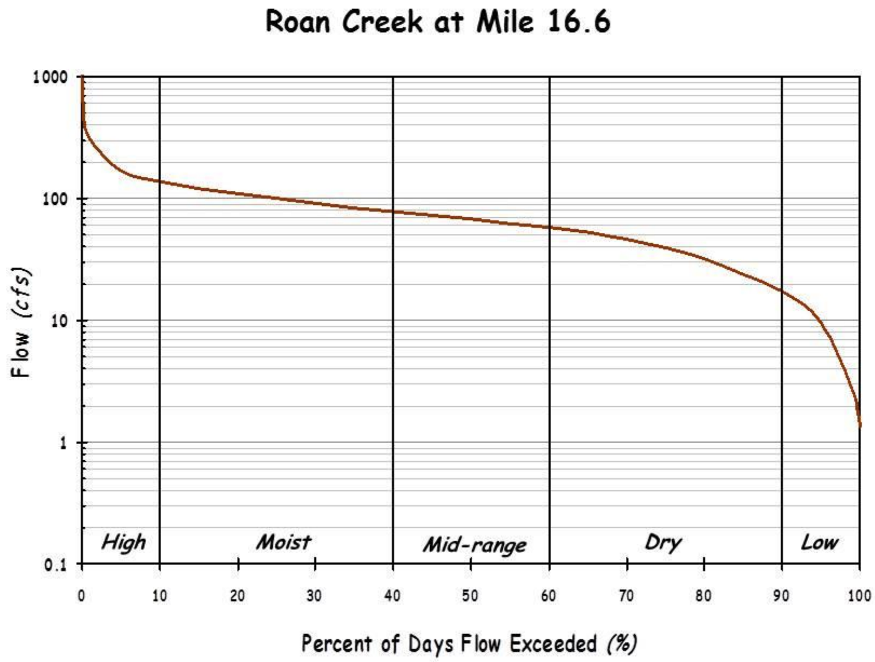

Figure C-1. Flow Duration Curve for Roan Creek at RM 16.6

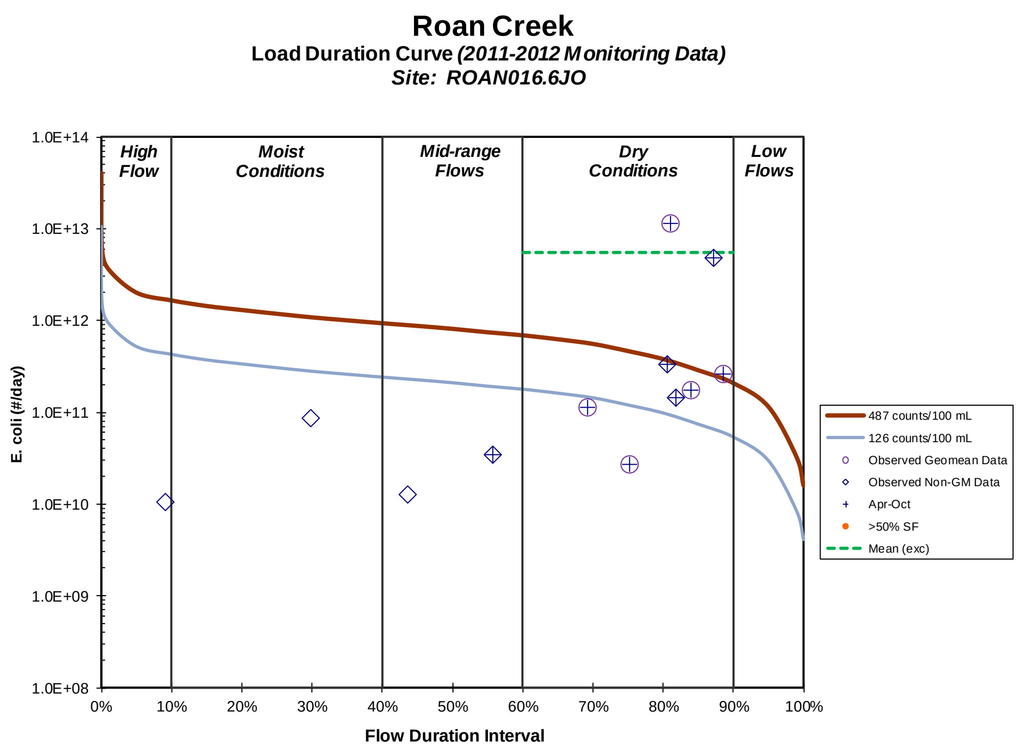

Figure C-2. E. Coli Load Duration Curve for Roan Creek at RM 16.6

Table C-1. TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Watauga River Watershed (HUC 06010103)

Impaired Waterbody Name	Impaired Waterbody ID	HUC-12 Subwatershed (06010103___)	TMDL	MOS	WLAs		LAs [c]
					WWTPs [a]	MS4s [b,c]	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/d/ac]	[CFU/d/ac]
Town Creek	TN06010103034 - 0300	0101	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$2.3 \times 10^{10} \times q_m$	$(1.097 \times 10^6 \times Q) - (7.592 \times 10^5)$ [f]	$(1.097 \times 10^6 \times Q) - (7.592 \times 10^5)$
Roan Creek	TN06010103034 – 2000	0102/0104 [d]	$1.2 \times 10^{10} \times Q$	$1.2 \times 10^{9} \times Q$	$1.2 \times 10^{10} \times q_m$	$(1.846 \times 10^5 \times Q) - (2.448 \times 10^5)$ [f]	$(1.846 \times 10^5 \times Q) - (2.448 \times 10^5)$
Sink Branch	TN06010103020T - 0200	0306 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(2.262 \times 10^7 \times Q) - (2.519 \times 10^7 \times q_d)$ [e,f]	$(2.262 \times 10^7 \times Q) - (2.519 \times 10^7 \times q_d)$ [e]
Buffalo Creek	TN06010103011 - 1000	0502	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(8.297 \times 10^5 \times Q) - (9.239 \times 10^5 \times q_d)$ [e]	$(8.297 \times 10^5 \times Q) - (9.239 \times 10^5 \times q_d)$ [e]
Powder Branch	TN06010103011 - 0100	0502 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(6.701 \times 10^6 \times Q) - (7.462 \times 10^6 \times q_d)$ [e]	$(6.701 \times 10^6 \times Q) - (7.462 \times 10^6 \times q_d)$ [e]
Toll Branch	TN06010103011 - 0200	0502 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(7.880 \times 10^6 \times Q) - (8.774 \times 10^6 \times q_d)$ [e]	$(7.880 \times 10^6 \times Q) - (8.774 \times 10^6 \times q_d)$ [e]
Sinking Creek	TN06010103046 - 1000	0503 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(2.325 \times 10^6 \times Q) - (2.588 \times 10^6 \times q_d)$ [e]	$(2.325 \times 10^6 \times Q) - (2.588 \times 10^6 \times q_d)$ [e]
Brush Creek	TN06010103009 - 1000	0504	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(1.981 \times 10^6 \times Q) - (2.206 \times 10^6 \times q_d)$ [e]	$(1.981 \times 10^6 \times Q) - (2.206 \times 10^6 \times q_d)$ [e]
Davis Branch	TN06010103008 - 0400	0505 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(1.935 \times 10^7 \times Q) - (2.154 \times 10^7 \times q_d)$ [e]	$(1.935 \times 10^7 \times Q) - (2.154 \times 10^7 \times q_d)$ [e]
Gap Creek	TN06010103008 - 0800	0505 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(3.390 \times 10^6 \times Q) - (3.775 \times 10^6 \times q_d)$ [e]	$(3.390 \times 10^6 \times Q) - (3.775 \times 10^6 \times q_d)$ [e]
Knob Creek	TN06010103635 - 1000	0506	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(1.523 \times 10^6 \times Q) - (1.696 \times 10^6 \times q_d)$ [e]	$(1.523 \times 10^6 \times Q) - (1.696 \times 10^6 \times q_d)$ [e]
Cobb Creek	TN06010103635 - 0200	0506 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(7.094 \times 10^6 \times Q) - (7.899 \times 10^6 \times q_d)$ [e]	$(7.094 \times 10^6 \times Q) - (7.899 \times 10^6 \times q_d)$ [e]
Cash Hollow Creek	TN06010103635 - 0100	0506 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(1.145 \times 10^7 \times Q) - (1.275 \times 10^7 \times q_d)$ [e]	$(1.145 \times 10^7 \times Q) - (1.275 \times 10^7 \times q_d)$ [e]
Boones Creek	TN06010103006 - 1000	0507 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(1.862 \times 10^6 \times Q) - (2.074 \times 10^6 \times q_d)$ [e]	$(1.862 \times 10^6 \times Q) - (2.074 \times 10^6 \times q_d)$ [e]
Carroll Creek	TN06010103006 - 0100	0507 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3 \times 10^{10} \times q_m)$ [e]	$(1.096 \times 10^7 \times Q) - (1.220 \times 10^7 \times q_d)$ [e]	$(1.096 \times 10^7 \times Q) - (1.220 \times 10^7 \times q_d)$ [e]

Table C-1 (cont'd). TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Watauga River Watershed (HUC 06010103)

Impaired Waterbody Name	Impaired Waterbody ID	HUC-12 Subwatershed (06010103___)	TMDL	MOS	WLAs		LAs [c]
					WWTPs [a]	MS4s [b,c]	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/d/ac]	[CFU/d/ac]
Darr Creek	TN06010103001T - 0100	0508 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(1.065 \times 10^{7} \times Q) - (1.186 \times 10^{7} \times q_d)$ [e]	$(1.065 \times 10^{7} \times Q) - (1.186 \times 10^{7} \times q_d)$ [e]
Reedy Creek	TN06010103061 - 1000	0508 [d]	$2.3 \times 10^{10} \times Q$	$2.3 \times 10^{9} \times Q$	$(2.3\times10^{10} \times q_m)$ [e]	$(5.871 \times 10^{6} \times Q) - (6.537 \times 10^{6} \times q_d)$ [e]	$(5.871 \times 10^{6} \times Q) - (6.537 \times 10^{6} \times q_d)$ [e]

Notes: Q = Mean Daily In-stream Flow (cfs).
q_m = Mean Daily WWTP Discharge (cfs)
q_d = Facility (WWTP) Design Flow (cfs)

a. WLAs for WWTPs are expressed as E. coli loads (CFU/day). All current and future WWTPs must meet water quality standards as specified in their NPDES permit.

b. Applies to any MS4 discharge loading in the subwatershed. Future MS4s will be assigned waste load allocations (WLAs) consistent with load allocations (LAs) assigned to precipitation induced nonpoint type sources. Compliance is achieved by meeting in-stream single-sample E. coli concentrations of ≤ 941 CFU/100 mL (or 487 CFU/100 mL for lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters). Delisting is achieved by meeting in-stream geomean sample E. coli concentrations of ≤ 126 CFU/100 mL.

c. WLAs and LAs expressed as a "per acre" load are calculated based on the drainage area at the pour point of the HUC-12 subwatershed or drainage area (see Table A-1). As regulated MS4 area increases (due to future growth and/or new MS4 designation), unregulated LA area decreases by an equivalent amount. The sum will continue to equal total subwatershed area.

d. Waterbody Drainage Area (DA) is not coincident with HUC-12(s).

e. No WWTPs currently discharging into or upstream of the waterbody. (Expression is future growth term for new WWTPs.)

f. No MS4s currently located in the subwatershed drainage area. (Expression is future growth term for expanding or newly designated MS4s.)

APPENDIX D

Hydrodynamic Modeling Methodology

D.1 Model Selection

The Windows version of Hydrologic Simulation Program - Fortran (HSPF) was selected for flow simulation of pathogen-impaired waters in the subwatersheds of the Watauga River watershed. HSPF is a watershed model capable of performing flow routing through stream reaches.

D.2 Model Set Up

The Watauga River watershed was delineated into subwatersheds in order to facilitate model hydrologic calibration. Boundaries were constructed so that subwatershed "pour points" coincided with HUC-12 delineations, 303(d)-listed waterbodies, and water quality monitoring stations. Watershed delineation was based on the NHD stream coverage and Digital Elevation Model (DEM) data. This discretization facilitates simulation of daily flows at water quality monitoring stations.

Several computer-based tools were utilized to generate input data for the WinHSPF model. ArcMap and WCS, GIS tools, were used to display, analyze, and compile available information to support hydrology model simulations for selected subwatersheds. This information includes land use categories, point source dischargers, soil types and characteristics, population data (human and livestock), and stream characteristics.

An important factor influencing model results is the precipitation data used for the simulation. Weather data from multiple meteorological stations were available for the time period from January 1970 through December 2013. Meteorological data for a selected 11-year period were used for all simulations. The first year of this period was used for model stabilization with simulation data from the subsequent 10-year period used for TMDL analysis. In the case of Lick Creek (station 03467000), a period of less than 10 years was used for calibration because the gage did not have a full 10-year period of continuous record. Meteorological data from the Bristol Tri-Cities Airport were used for hydrologic calibration.

D.3 Model Calibration

Hydrologic calibration of the watershed model involves comparison of simulated streamflow to historic streamflow data from USGS stream gaging stations for the same period of time. Three USGS continuous record stations located in or near the Watauga River watershed were selected as the basis of the hydrology calibration. Station 03479000 is located on Watauga River near Sugar Grove, NC, within Level IV ecoregion 66D, has a geology factor of 75, and has a drainage area of 92.1 square miles. Calibration parameters determined for station 03479000 were used for impaired waterbodies lying in ecoregion 66 with a geology factor of 75. Station 03466228 is located on Sinking Creek at Afton, TN, within Level IV ecoregion 67F, has a geology factor of 120, and has a drainage area of 13.7 square miles. Calibration parameters determined for station 03466228 were used for impaired waterbodies with small drainage areas lying in ecoregions 67F with geology factors of 100 or 120. Station 03467000 is located on Lick Creek at Mohawk, TN, within Level IV ecoregions 67G, 67H, and 67I, has a geology factor of 34, and has a drainage area of 220 square miles. Calibration parameters determined for station 03467000 were used for larger drainage areas lying in ecoregions 67f and 67G with a geology factor of 50.

Initial values for hydrologic variables were taken from an EPA developed default data set. During the calibration process, model parameters were adjusted within reasonable constraints until acceptable agreement was achieved between simulated and observed streamflow. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge.

The results of the hydrologic calibrations for Watauga River near Sugar Grove, NC, (USGS Station 03479000), Sinking Creek at Afton, TN, (USGS Station 03466228), and Lick Creek at Mohawk, TN, (USGS Station 03467000) are shown in Tables D-1 through D-3 and Figures D-1 through D-6.

Table D-1. Hydrologic Calibration Summary: Watauga River near Sugar Grove, NC (USGS 03479000)

Simulation Name:	USGS03479000	**Simulation Period:**	
		Watershed Area (ac):	36840.00
		Watershed Area (mi^2):	57.56
Period for Flow Analysis			
Begin Date:	**10/01/98**	**Baseflow PERCENTILE:**	2.5
End Date:	**10/01/08**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**349.09**	Total Observed In-stream Flow:	**351.16**
Total of highest 10% flows:	**137.46**	Total of Observed highest 10% flows:	**125.91**
Total of lowest 50% flows:	**76.10**	Total of Observed Lowest 50% flows:	**70.85**
Simulated Summer Flow Volume (months 7-9):	**80.68**	Observed Summer Flow Volume (7-9):	**74.26**
Simulated Fall Flow Volume (months 10-12):	**94.44**	Observed Fall Flow Volume (10-12):	**77.54**
Simulated Winter Flow Volume (months 1-3):	**94.46**	Observed Winter Flow Volume (1-3):	**110.55**
Simulated Spring Flow Volume (months 4-6):	**79.52**	Observed Spring Flow Volume (4-6):	**88.81**
Total Simulated Storm Volume:	**287.50**	Total Observed Storm Volume:	**297.12**
Simulated Summer Storm Volume (7-9):	**65.32**	Observed Summer Storm Volume (7-9):	**60.82**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-0.59**	10	
Error in 50% lowest flows:	**7.41**	10	
Error in 10% highest flows:	**9.17**	15	
Seasonal volume error - Summer:	**8.64**	30	
Seasonal volume error - Fall:	**21.79**	30	
Seasonal volume error - Winter:	**-14.56**	30	
Seasonal volume error - Spring:	**-10.46**	30	
Error in storm volumes:	**-3.24**	20	
Error in summer storm volumes:	**7.39**	50	

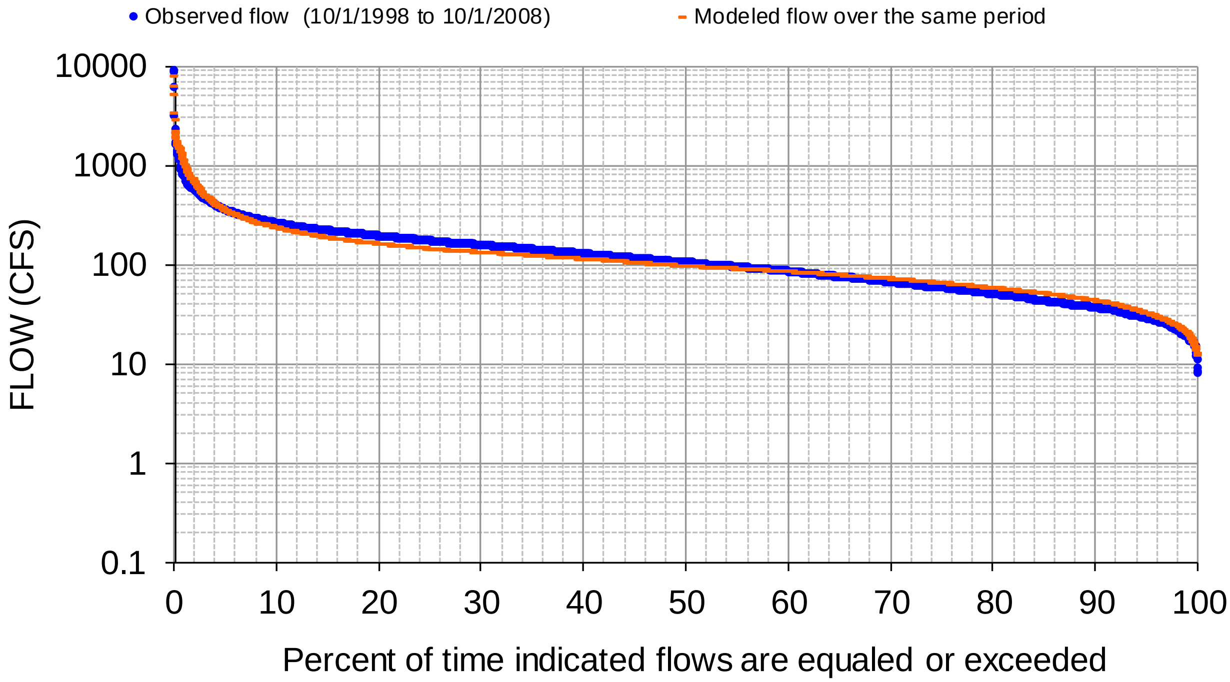

Figure D-1. Hydrologic Calibration: Watauga River, USGS 03479000 (WY 1999-2008)

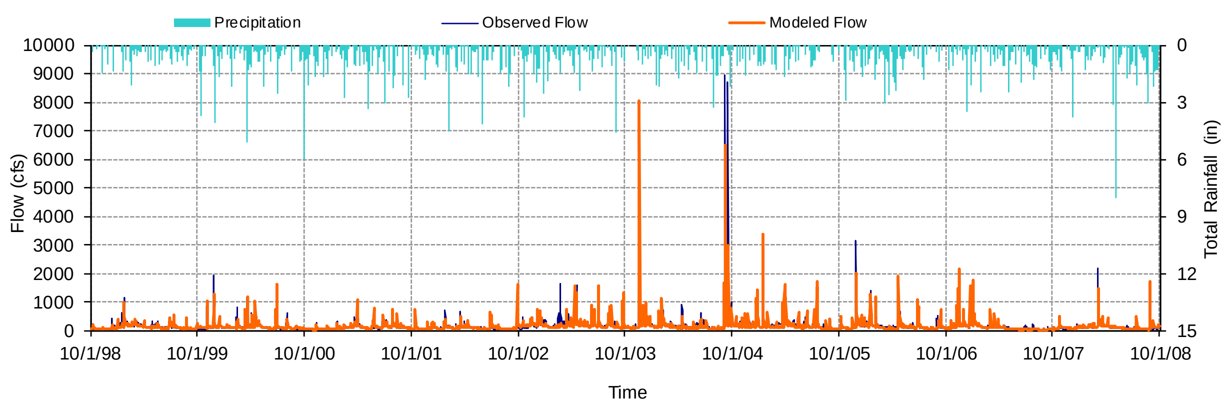

Figure D-2. 10-Year Hydrologic Comparison: Watauga River, USGS 03479000

Table D-2. Hydrologic Calibration Summary: Sinking Creek at Afton, TN (USGS 03466228)

Simulation Name:	USGS03466228	**Simulation Period:**	
		Watershed Area (ac):	8466.50
		Watershed Area (mi^2):	13.23
Period for Flow Analysis			
Begin Date:	**10/01/90**	**Baseflow PERCENTILE:**	2.5
End Date:	**10/01/00**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**153.07**	Total Observed In-stream Flow:	**150.21**
Total of highest 10% flows:	**49.03**	Total of Observed highest 10% flows:	**52.47**
Total of lowest 50% flows:	**33.39**	Total of Observed Lowest 50% flows:	**31.01**
Simulated Summer Flow Volume (months 7-9):	**21.12**	Observed Summer Flow Volume (7-9):	**19.96**
Simulated Fall Flow Volume (months 10-12):	**25.34**	Observed Fall Flow Volume (10-12):	**20.07**
Simulated Winter Flow Volume (months 1-3):	**64.58**	Observed Winter Flow Volume (1-3):	**65.69**
Simulated Spring Flow Volume (months 4-6):	**42.02**	Observed Spring Flow Volume (4-6):	**44.48**
Total Simulated Storm Volume:	**129.50**	Total Observed Storm Volume:	**119.43**
Simulated Summer Storm Volume (7-9):	**15.20**	Observed Summer Storm Volume (7-9):	**12.20**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**1.90**	10	
Error in 50% lowest flows:	**7.67**	10	
Error in 10% highest flows:	**-6.55**	15	
Seasonal volume error - Summer:	**5.80**	30	
Seasonal volume error - Fall:	**26.24**	30	
Seasonal volume error - Winter:	**-1.69**	30	
Seasonal volume error - Spring:	**-5.53**	30	
Error in storm volumes:	**8.44**	20	
Error in summer storm volumes:	**24.57**	50	

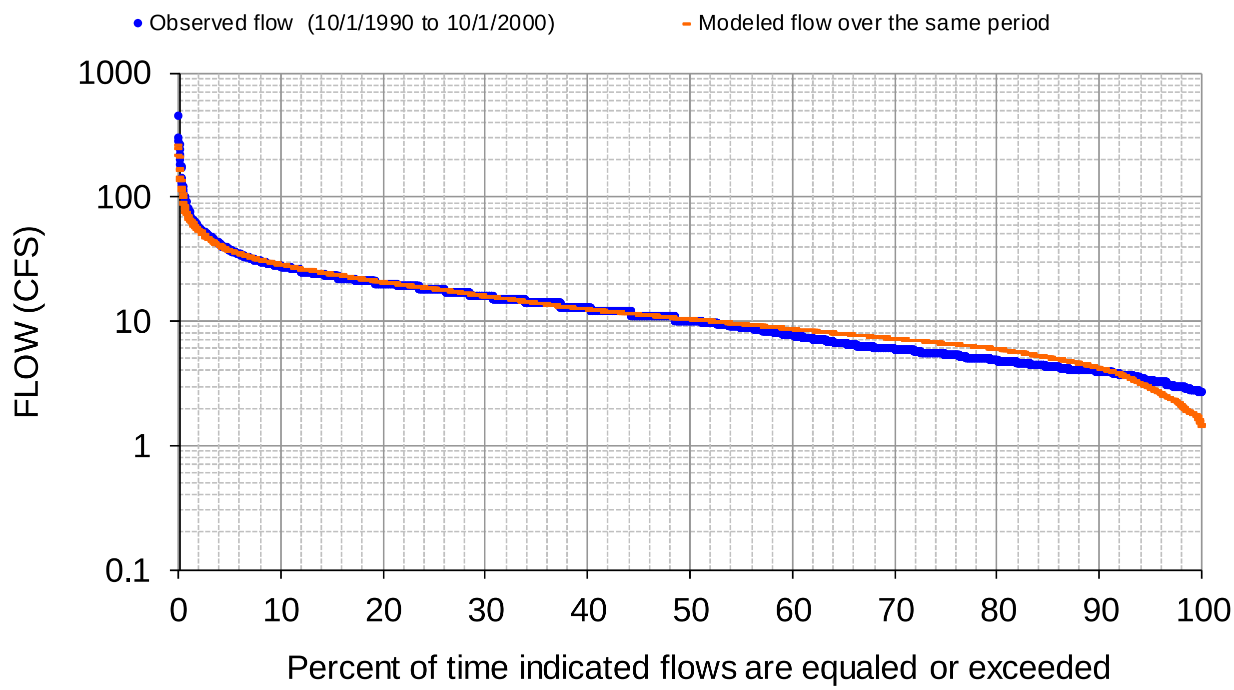

Figure D-3. Hydrologic Calibration: Sinking Creek at Afton, USGS 03466228 (WY 1991-2000)

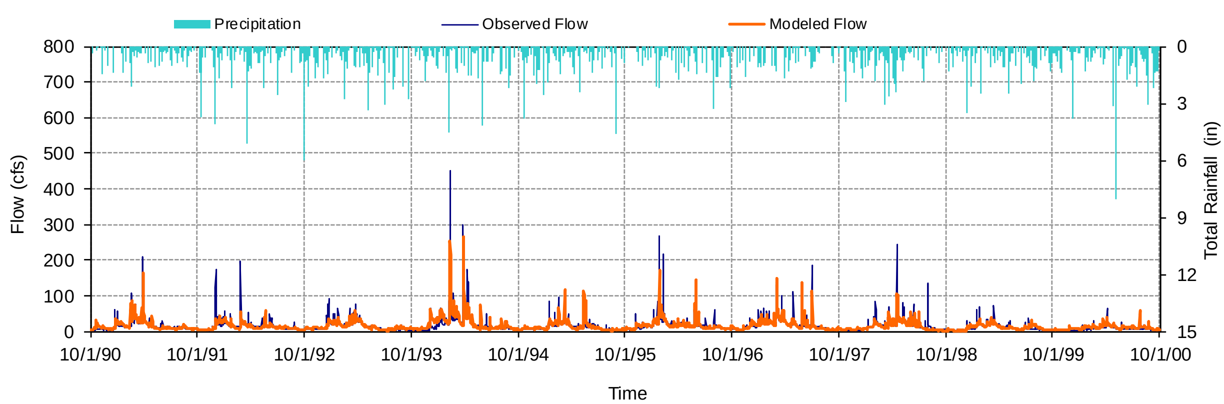

Figure D-4. 10-year Hydrologic Comparison: Sinking Creek at Afton, USGS 03466228

Table D-3. Hydrologic Calibration Summary: Lick Creek at Mohawk, TN (USGS 03467000)

	Simulation Name:	USGS03467000	**Simulation Period:**	
			Watershed Area (ac):	137770.00
			Watershed Area (mi^2):	215.27
	Period for Flow Analysis			
	Begin Date:	**10/01/01**	**Baseflow PERCENTILE:**	2.5
	End Date:	**10/01/08**	*Usually 1%-5%*	
	Total Simulated In-stream Flow:	**81.86**	Total Observed In-stream Flow:	**83.34**
	Total of highest 10% flows:	**36.46**	Total of Observed highest 10% flows:	**42.18**
	Total of lowest 50% flows:	**9.14**	Total of Observed Lowest 50% flows:	**8.98**
	Simulated Summer Flow Volume (months 7-9):	**16.42**	Observed Summer Flow Volume (7-9):	**8.36**
	Simulated Fall Flow Volume (months 10-12):	**18.69**	Observed Fall Flow Volume (10-12):	**17.70**
	Simulated Winter Flow Volume (months 1-3):	**26.55**	Observed Winter Flow Volume (1-3):	**34.06**
	Simulated Spring Flow Volume (months 4-6):	**20.20**	Observed Spring Flow Volume (4-6):	**23.21**
	Total Simulated Storm Volume:	**78.28**	Total Observed Storm Volume:	**78.50**
	Simulated Summer Storm Volume (7-9):	**15.52**	Observed Summer Storm Volume (7-9):	**7.16**
	Errors (Simulated-Observed)		*Recommended Criteria*	Last run
	Error in total volume:	**-1.78**	10	
	Error in 50% lowest flows:	**1.77**	10	
	Error in 10% highest flows:	**-13.56**	15	
***	Seasonal volume error - Summer:	**96.37**	30	
	Seasonal volume error - Fall:	**5.56**	30	
	Seasonal volume error - Winter:	**-22.05**	30	
	Seasonal volume error - Spring:	**-12.97**	30	
	Error in storm volumes:	**-0.28**	20	
***	Error in summer storm volumes:	**116.81**	50	

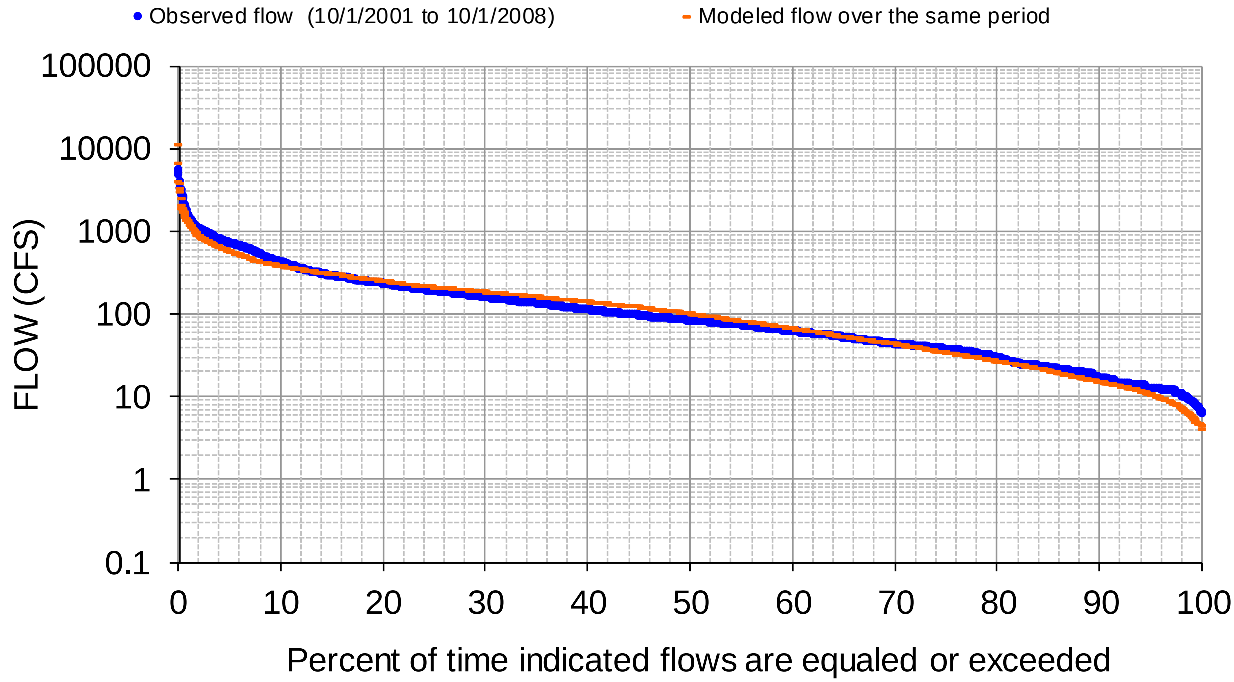

Figure D-5. Hydrologic Calibration: Lick Creek, USGS 03467000 (WY 2002-2008)

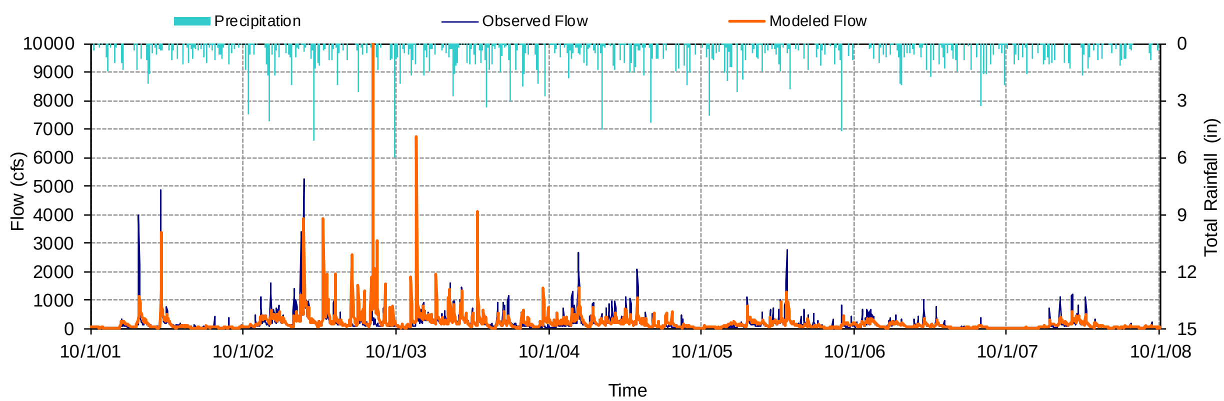

Figure D-6. 7-year Hydrologic Comparison: Lick Creek, USGS 03467000

APPENDIX E

Source Area Implementation Strategy

All impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas have been classified according to their respective source area types in Section 9.5, Table 9. The implementation for each will be prioritized according to the source area classifications and the information provided in Sections 9.5.1 and 9.5.2, with examples provided in Sections E.1 and E.2, below. For all impaired waterbodies, the determination of source area types serves to identify the predominant sources contributing to impairment (i.e., those that should be targeted initially for implementation). It is not intended to imply that sources in other landuse areas are not contributors to impairment and/or to grant an exemption from addressing other source area contributions with implementation strategies and corresponding load reduction. For mixed use areas, implementation will address both urban and agricultural areas, at a minimum.

E.1 Urban Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas identified as predominantly urban source area types, Knob Creek provides an example for implementation analysis. Knob Creek was selected because it has a high percentage of urban area.

The majority of the Knob Creek subwatershed, in HUC-12 060101030506, lies in Johnson City. The drainage area for Knob Creek is approximately 13,589 acres (21.2 mi^2); therefore, four flow zones were used for the duration curve analysis (see Sect. 9.1.1).

The flow duration curve for Knob Creek at mile 3.7 was constructed using simulated daily mean flow for the period from 10/1/02 through 9/30/12 (mile 3.7 corresponds to the location of monitoring station KNOB003.7WN). This flow duration curve is shown in Figure E-1 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record. Flow duration curves for other impaired waterbodies were developed using a similar procedure (Appendix C).

The E. coli LDC for Knob Creek (Figure E-2) was analyzed to determine the frequency with which observed daily water quality loads exceed the E. coli target maximum daily loading (941 CFU/100 mL x flow [cfs] x conversion factor) under four flow conditions (low, mid-range, moist, and high). Observation of the plot illustrates that exceedances during the most recent 5-year period occurred during a variety of flow conditions (Table E-1), indicating that the Knob Creek subwatershed may be impacted by nonpoint-type sources (including regulated stormwater runoff, dominant during high flow/runoff conditions) and point-type sources (dominant during low flow/baseflow conditions). According to hydrograph separation analysis, the exceedance which occurred under high flow conditions also took place during a time when stormflow dominated (greater than 50% stormflow). The remaining exceedances, occurring under mid-range and low flow conditions, took place when stormflow did not dominate. This also suggests that the Knob Creek drainage area may be impacted by both nonpoint-type and point-type sources.

Results indicate the implementation strategy for the Knob Creek subwatershed will require BMPs targeting both point and nonpoint type sources. Table E-1 presents an allocation table of LDC analysis statistics for Knob Creek E. coli and implementation strategies for each source category covering the entire range of flow (Stiles, 2003). The implementation strategies listed in Table E-1 are a subset of the categories of BMPs and implementation strategies available for application to the Watauga River watershed for reduction of E. coli loading and mitigation of water quality impairment from urban sources. Targeted implementation strategies and LDC analysis statistics for other impaired waterbodies and corresponding HUC-12 subwatersheds and drainage areas identified as predominantly urban source area types can be derived from the information and results available in Tables 10 and E-62.

Table E-62 presents LDC analyses (TMDLs, WLAs, LAs, and MOS) and PLRGs for all flow zones for all E. coli impaired waterbodies in the Watauga River watershed.

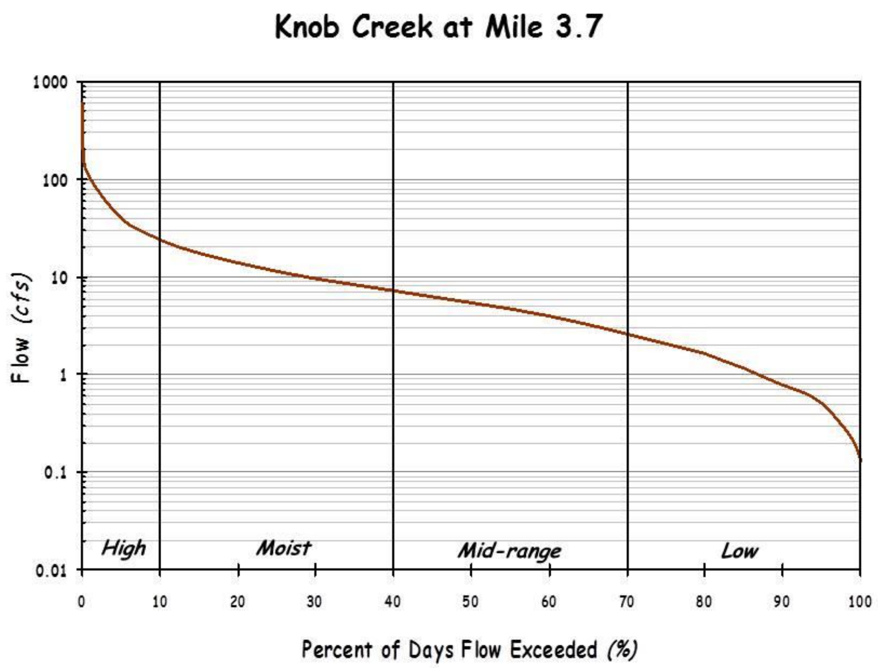

Figure E-1. Flow Duration Curve for Knob Creek at RM 3.7

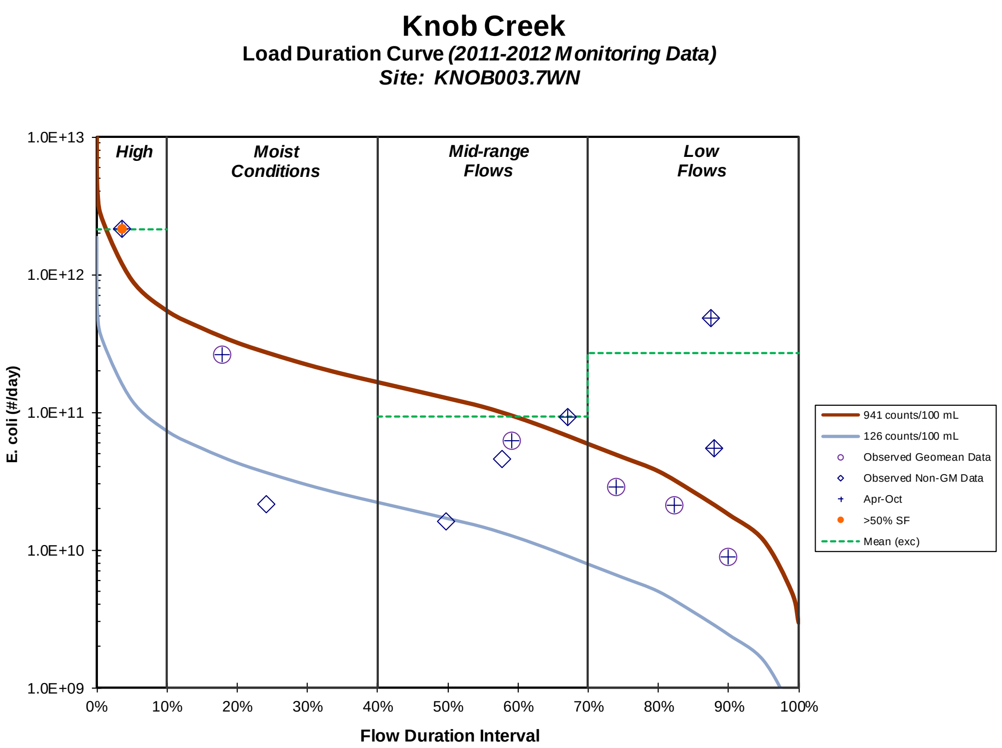

Figure E-2. E. Coli Load Duration Curve for Knob Creek at RM 3.7

Table E-1. Load Duration Curve Summary for Implementation Strategies (Example: Knob Creek subwatershed, in HUC-12 060101030506) (4 Flow Zones)

Hydrologic Condition		High	Moist	Mid-range	Low*
% Time Flow Exceeded		0-10	10-40	40-70	70-100
Knob Creek (060101030506) At RM3.7	Number of Samples	1	2	4	5
	% > 941 CFU/100 mL[1]	100.0	0.0	25.0	40.0
	Load Reduction[2]	45.7%	NR	27.6%	78.3%
TMDL (CFU/day)		4.745E+11	1.375E+11	5.712E+10	1.380E+10
Margin of Safety (CFU/day)		4.745E+10	1.375E+10	5.712E+09	1.380E+09
WLA (WWTPs) (CFU/day)[5]		(4.342E+06) x q_m	(4.342E+06) x q_m	(4.342E+06) x q_m	(4.342E+06) x q_m
WLAs (MS4s) (CFU/day/acre)[3,5]		(8.062E+07) – ([4.342E+06] x q_d)	(2.337E+07) – ([4.342E+06] x q_d)	(9.705E+06) – ([4.342E+06] x q_d)	(2.345E+06) – ([4.342E+06] x q_d)
LA (CFU/day/acre)[3,5]		(8.062E+07) – ([4.342E+06] x q_d)	(2.337E+07) – ([4.342E+06] x q_d)	(9.705E+06) – ([4.342E+06] x q_d)	(2.345E+06) – ([4.342E+06] x q_d)
Implementation Strategies[4]					
Municipal NPDES			L	M	H
Stormwater Management			H	H	
SSO Mitigation		H	M	L	
Collection System Repair			H	M	
Septic System Repair			L	M	M
Potential for source area contribution under given flow condition (H: High; M: Medium; L: Low)					

q_d = Facility (WWTP) Design Flow (cfs)

q_m = Mean Daily WWTP Discharge (cfs)

* The Low Flow zone represents the critical condition for E. coli loading in the Knob Creek subwatershed.

1 Tennessee Maximum daily water quality criterion for E. coli.

2 Reductions (percent) based on mean of observed percent load reductions in range.

3 LAs and MS4s are expressed as daily load per unit area in order to provide for future changes in the distribution of LAs and MS4s (WLAs).

4 Example Best Management Practices for Urban Source reduction. Actual BMPs applied may vary and should not be limited according to this grouping.

5 For cases in which there is no WWTP currently discharging to the waterbody, the variable q_d or q_m will be retained in the equation as a placeholder for any future WWTPs.

E.2 Agricultural Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas identified as predominantly agricultural source area types, Boones Creek provides an example for implementation analysis.

The Boones Creek drainage area, part of HUC-12 060101030507, lies in a partially urbanized area of Washington County. The drainage area for Boones Creek is approximately 11,115 acres (17.4 mi^2); therefore, four flow zones were used for the duration curve analysis (see Sect. 9.1.1). The landuse for this portion of Boones Creek is approximately 43.6% agricultural, with the remainder between forested and urban. The area near the mouth of Boones Creek is more heavily urbanized than the remainder of the watershed. Therefore, analysis will be based on the drainage area associated with monitoring station BOONE003.7WN.

The flow duration curve for Boones Creek at RM3.7 was constructed using simulated daily mean flow for the period from 10/1/02 through 9/30/12. This flow duration curve is shown in Figure E-3 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record. Flow duration curves for other impaired waterbodies were developed using a similar procedure (see Appendix C).

The E. coli LDC for Boones Creek at RM3.7 (Figure E-4) was analyzed to determine the frequency with which observed daily water quality loads exceed the E. coli target maximum daily loading (941 CFU/100 mL x flow [cfs] x conversion factor) under four flow conditions (low, mid-range, moist, and high). Observation of the plot illustrates that exceedances during the most recent 5-year period occurred under a variety of flow conditions (see Table E-2), indicating that the Boones Creek drainage area upstream of RM3.7 may be impacted by both point-type sources and nonpoint-type sources. However, according to hydrograph separation analysis, the majority of the samples were taken when stormflow was not dominant (less than 20% stormflow), suggesting that the Boones Creek drainage area upstream of RM3.7 may be impacted predominantly by point-type sources.

Results indicate the implementation strategy for the Boones Creek drainage area upstream of RM3.7 will require BMPs targeting point-type sources (dominant during low flow/baseflow conditions). Table E-2 presents an allocation table of LDC analysis statistics for Boones Creek E. coli and targeted implementation strategies for each source category covering the entire range of flow (Stiles, 2003). The implementation strategies listed in Table E-2 are a subset of the categories of BMPs and implementation strategies available for application to the Watauga River watershed for reduction of E. coli loading and mitigation of water quality impairment from agricultural sources. Targeted implementation strategies and LDC analysis statistics for other impaired waterbodies and corresponding HUC-12 subwatersheds and drainage areas identified as predominantly agricultural source area types can be derived from the information and results available in Tables 11 and E-62.

LDCs for other impaired waterbodies were developed using a similar procedure (Appendix C) and are shown in Figures E-5 through E-33. Table E-62 presents LDC analyses (TMDLs, WLAs, LAs, and MOS) and PLRGs for all flow zones for all E. coli impaired waterbodies in the Watauga River watershed.

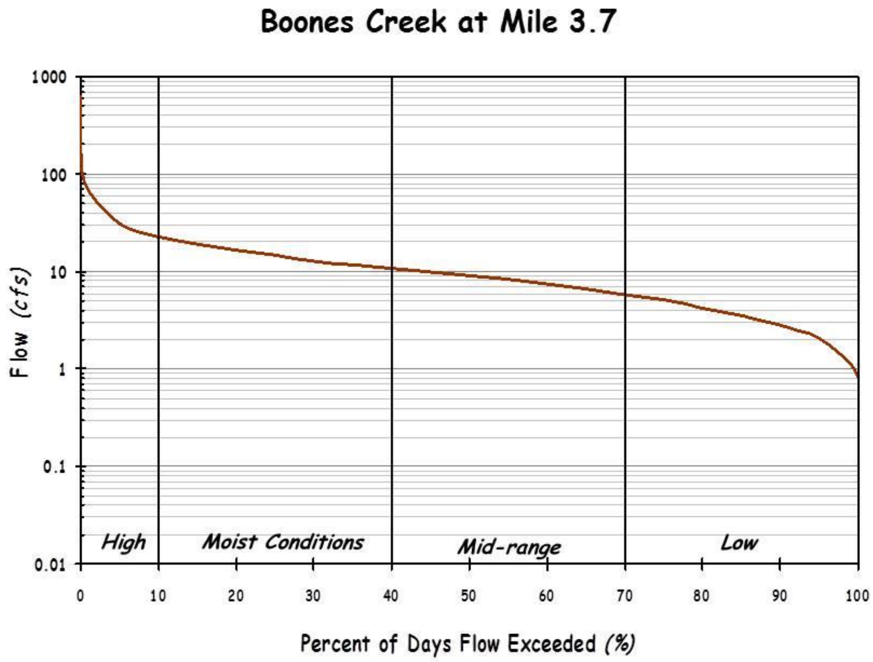

Figure E-3. Flow Duration Curve for Boones Creek at RM 3.7

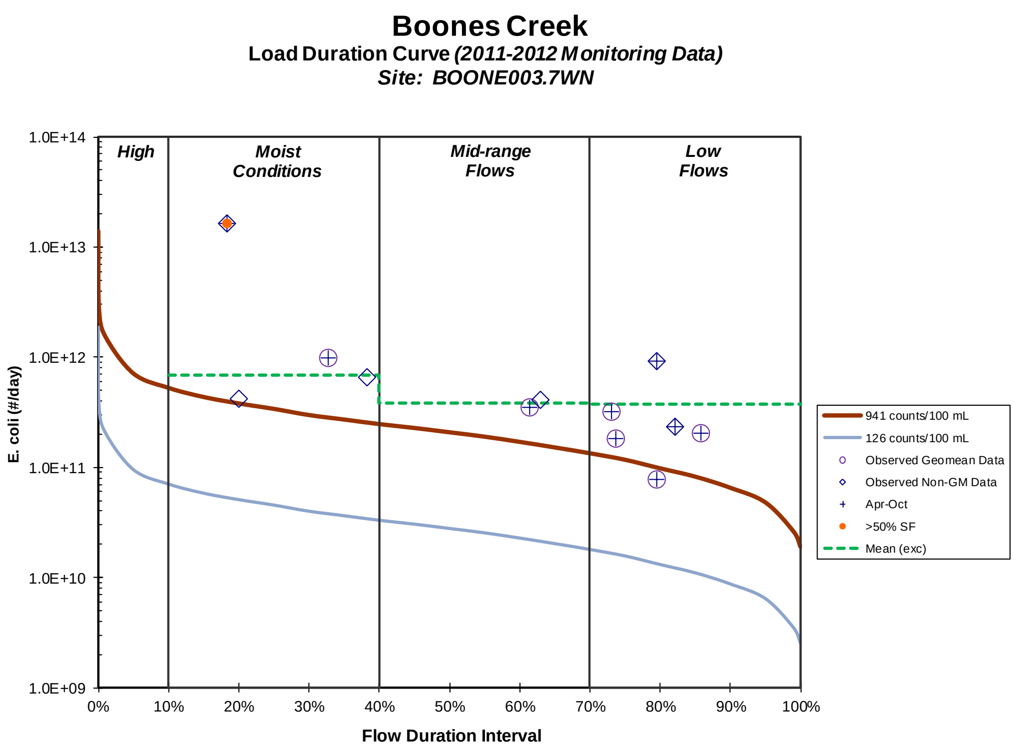

Figure E-4. E. Coli Load Duration Curve for Boones Creek at RM 3.7

Table E-2. Load Duration Curve Summary for Implementation Strategies (Example: Boones Creek subwatershed, HUC-12 060101030507) (4 Flow Zones)

Hydrologic Condition		High	Moist	Mid-range	Low*
% Time Flow Exceeded		0-10	10-40	40-70	70-100
Boones Creek (060101030507) At RM3.7	Number of Samples	0	4	2	6
	% > 941 CFU/100 mL[1]	0.0	100.0	100.0	83.3
	Load Reduction[2]	NA	60.0%	56.9%	61.2%
TMDL (CFU/day)		7.100E+11	3.388E+11	1.895E+11	8.211E+10
Margin of Safety (CFU/day)		7.100E+10	3.388E+10	1.895E+10	8.211E+09
WLA (WWTPs) (CFU/day)[5]		(3.536E+06) x q_m	(3.536E+06) x q_m	(3.536E+06) x q_m	(3.536E+06) x q_m
WLAs (MS4s) (CFU/day/acre)[3,5]		(9.825E+07) – ([3.536E+06] x q_d)	(4.688E+07) – ([3.536E+06] x q_d)	(2.623E+07) – ([3.536E+06] x q_d)	(1.136E+07) – ([3.536E+06] x q_d)
LA (CFU/day/acre)[3,5]		(9.825E+07) – ([3.536E+06] x q_d)	(4.688E+07) – ([3.536E+06] x q_d)	(2.623E+07) – ([3.536E+06] x q_d)	(1.136E+07) – ([3.536E+06] x q_d)
Implementation Strategies[4]					
Pasture and Hayland Management		H	H	M	L
Livestock Exclusion				M	H
Fencing				M	H
Manure Management		H	H	M	L
Riparian Buffers		L	M	H	M
Potential for source area contribution under given flow condition (H: High; M: Medium; L: Low)					

q_d = Facility (WWTP) Design Flow (cfs)
q_m = Mean Daily WWTP Discharge (cfs)
* The Low Flow zone represents the critical conditions for E. coli loading in the Boones Creek drainage area upstream of RM3.7.
1 Tennessee Maximum daily water quality criterion for E. coli.
2 Reductions (percent) based on mean of observed percent load reductions in range.
3 LAs and MS4s are expressed as daily load per unit area in order to provide for future changes in the distribution of LAs and MS4s (WLAs).
4 Example Best Management Practices for Agricultural Source reduction. Actual BMPs applied may vary and should not be limited according to this grouping.
5 For cases in which there is no WWTP currently discharging to the waterbody, the variable q_d or q_m will be retained in the equation as a placeholder for any future WWTPs.

E.3 Forestry Source Areas

There are no impaired waterbodies with corresponding HUC-12 subwatersheds or drainage areas classified as source area type predominantly forested, with the predominant source category being wildlife, in the Watauga River watershed.

E.4 Calculation of Percent Load Reduction Goals and Determination of Critical Flow Zones

In order to facilitate implementation, corresponding percent reductions in loading required to decrease existing, in-stream E. coli loads to TMDL target levels (percent load reduction goals) were calculated. As a result, critical flow zones were determined and subsequently verified by secondary analyses. The following example is from Knob Creek at mile 3.7.

1. For each flow zone, the mean of the percent exceedances of individual loads relative to their respective target maximum loads (at their respective PDFEs) was calculated. Individual loads with no required load reduction are not included in the mean calculation. The following illustrates the calculation of the PLRG for the low flow zone:

Date	Sample Conc. (CFU/100 mL)	Flow (cfs)	Existing Load (CFU/Day)	Target (TMDL) Load (CFU/Day)	Percent Reduction
9/21/11	548	2.15	2.88E+10	4.95E+10	
9/28/11	613	1.41	2.11E+10	3.24E+10	
6/12/12	20,640	0.957	4.83E+11	2.20E+10	95.4
7/14/11	2,420	0.922	5.46E+10	2.12E+10	61.1
10/5/11	461	0.789	8.90E+09	1.82E+10	
Percent Load Reduction Goal (PLRG) for Low Flow Conditions (Mean)					**78.3**

2. The PLRGs calculated for each of the flow zones, not including the high flow zone (see Section 9.1.1), were compared and the PLRG of the greatest magnitude indicates the critical flow zone for prioritizing implementation actions for Knob Creek.

   Example – *High Flow Zone Percent Load Reduction Goal = 45.7*
   Moist Conditions Flow Zone Percent Load Reduction Goal = NA
   Mid-Range Flow Zone Percent Load Reduction Goal = 27.6
   Low Flow Zone Percent Load Reduction Goal = 78.3

   Therefore, the critical flow zone for prioritization of Knob Creek implementation activities is the Low Flow Zone and subsequently actions targeting point type source controls.

3. Due to the frequently limited availability of sampling data and subsequent randomness of distribution of samples by flow zone, the determination of the critical flow zone by PLRG calculation often has a high degree of uncertainty. Therefore, secondary analyses were conducted to verify or supplement the determination of the critical flow zones. For each flow zone, the percent of samples that exceed the E. coli TMDL target levels was calculated. For Knob Creek:

Flow Zone	Number of Samples	Samples > 941 CFU/100 mL	% > 941 CFU/100 mL
High	1	1	100.0
Moist	2	0	NR
Mid-Range	4	1	25.0
Low	5	2	40.0

Based on the number of exceedances in each flow zone, the critical flow zone for prioritization of Knob Creek implementation activities is the low flow zone. Whenever the two methods of determining critical flow zone produce different results, both flow zones should be targeted for implementation activities.

4. Lastly, emphasis (priority) should be placed on recent data versus historical data. If data from multiple watershed cycles is available, analysis of recent data (current cycle) versus the entire period of record, or previous cycles, may identify different critical areas for implementation.

Zone	Period of Record (2006-12)			Most Recent (2011-12)		
	# of samples	% Red.	% Exceed.	# of samples	% Red.	% Exceed.
High	2	45.7	50.0	1	45.7	100.0
Moist	5	81.3	20.0	2	NR	NA
Mid-Range	6	27.6	16.7	4	27.6	25.0
Low	11	72.6	27.3	5	78.3	40.0

The critical flow zone for prioritization of implementation activities for Knob Creek is confirmed as the same zone (low flow zone) as initial analyses indicated. (The high flow zone is excluded as discussed in section 9.1.1.) However, if a different flow zone, or zones, were identified, the flow zone(s) from analysis of recent data would have emphasis for implementation prioritization.

PLRGs and critical flow zones of the other impaired waterbodies were derived in a similar manner and are shown in Table E-62.

Geometric Mean Data

For cases where five or more samples were collected over a period of not more than 30 consecutive days, the geometric mean E. coli concentration was determined and compared to the target geometric mean E. coli concentration of 126 CFU/100 mL. If the sample geometric mean exceeded the target geometric mean concentration, the reduction required to reduce the sample geometric mean value to the target geometric mean concentration was calculated.

Example: *Monitoring Location = Knob Creek Mile 3.7*
Sampling Period = 9/7/11 – 10/5/11
Geometric Mean Concentration = 367.6 CFU/100 mL
Target Concentration = 126 CFU/100 mL
Reduction to Target = 65.7%

For impaired waterbodies where monitoring data are limited to geometric mean data only, results can be utilized for general indication of relative impairment and, when plotted on a load duration curve, may indicate areas for prioritization of implementation efforts. For impaired waterbodies where both types of data are available, geometric mean data may be utilized to supplement the results of the individual flow zone calculations.

Table E-3. Summary of Critical Conditions for Impaired Waterbodies in the Watauga River Watershed

Waterbody ID	Moist	Mid-Range	Dry	Low	Monitoring Station	Drainage Area (ac)
Boones Creek	✓				BOONE000.7WN	8,014
Brush Creek				✓	BRUSH000.7WN	9,380
Buffalo Creek				✓	BUFFA000.2CT	23,814
Carroll Creek				✓	CARRO000.5WN	1,573
Cash Hollow Creek				✓	CASH_G0.3WN	1,808
Cobb Creek				✓	COBB001.0WN	2,368
Darr Creek				✓	DARR001.2SU	1,485
Davis Branch				✓	DAVIS000.9CT	1,070
Gap Creek		✓			GAP000.1CT	6,106
Knob Creek				✓	KNOB003.7WN	5,297
Powder Branch				✓	POWDE000.4CT	3,089
Reedy Creek		✓			REEDY001.8WN	3,273
Roan Creek (034-2000)[a]			✓		ROAN016.6JO	42,819
Sink Branch				✓	SINK000.7JO	915
Sinking Creek				✓	SINKI000.6CT	6,456
Toll Branch				✓	TOLL000.3CT	2,627
Town Creek				✓	TOWN000.9JO	17,831

[a] Waterbody(ies) with 5 flow zones.

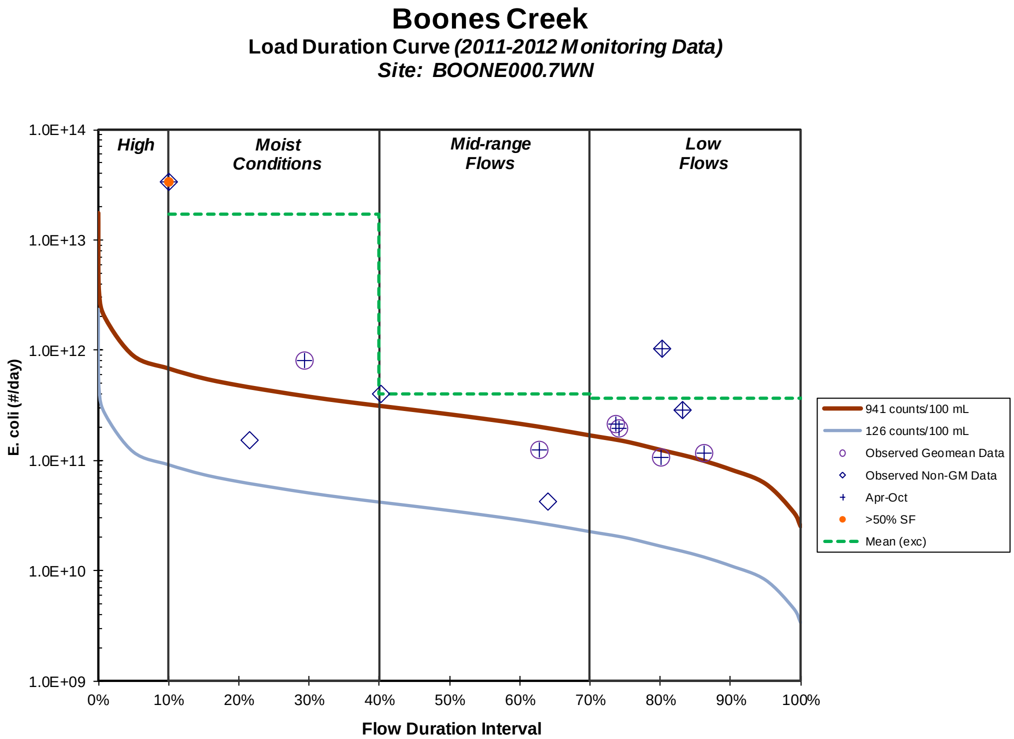

Figure E-5. E. Coli Load Duration Curve for Boones Creek – RM0.7

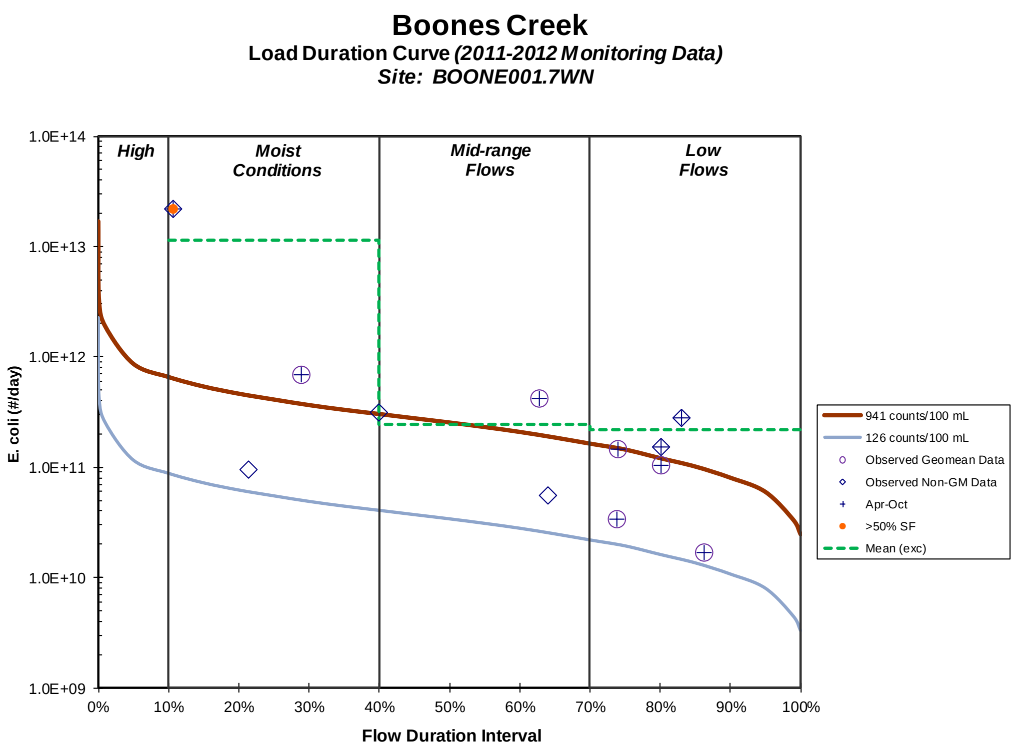

Figure E-6. E. Coli Load Duration Curve for Boones Creek – RM1.7

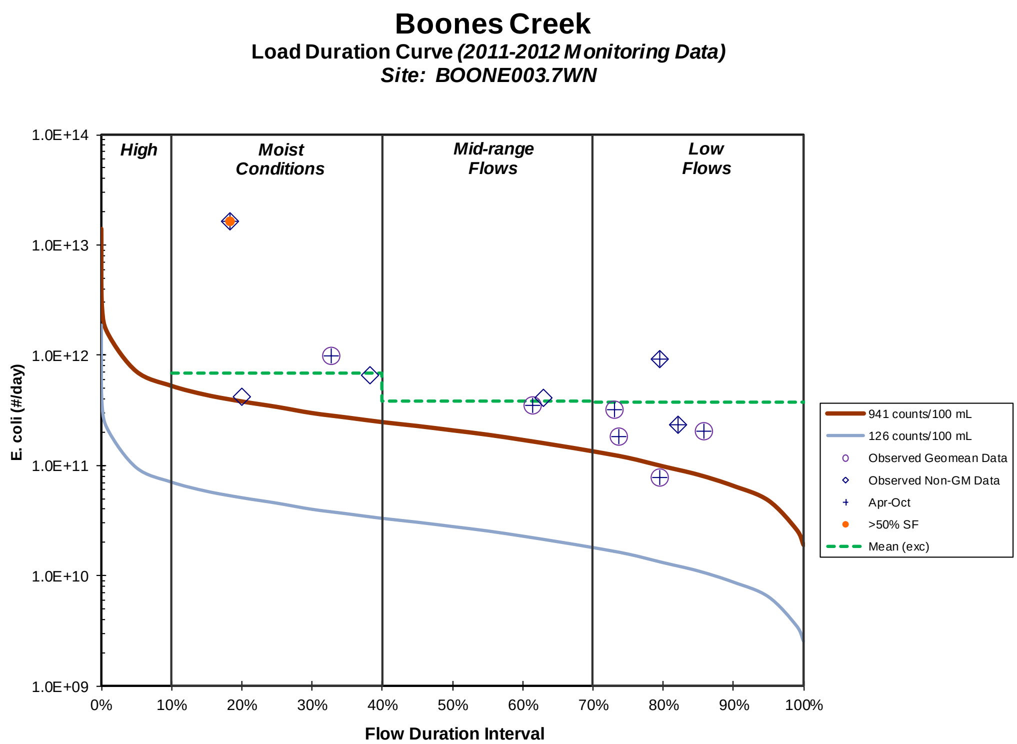

Figure E-7. E. Coli Load Duration Curve for Boones Creek – RM3.7

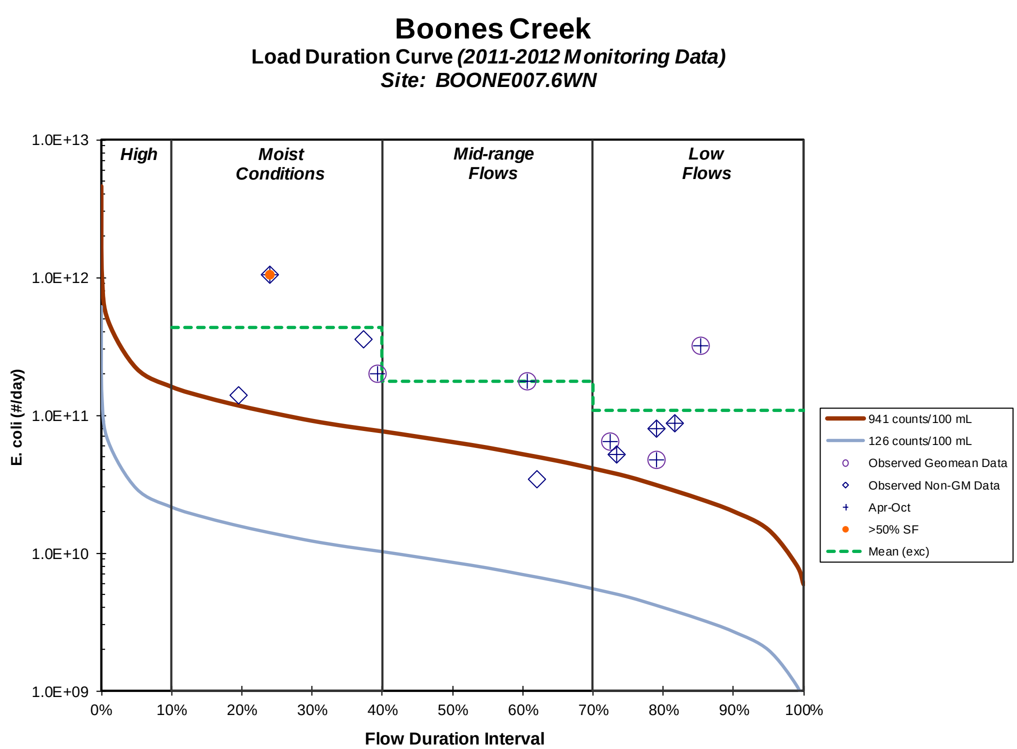

Figure E-8. E. Coli Load Duration Curve for Boones Creek – RM7.6

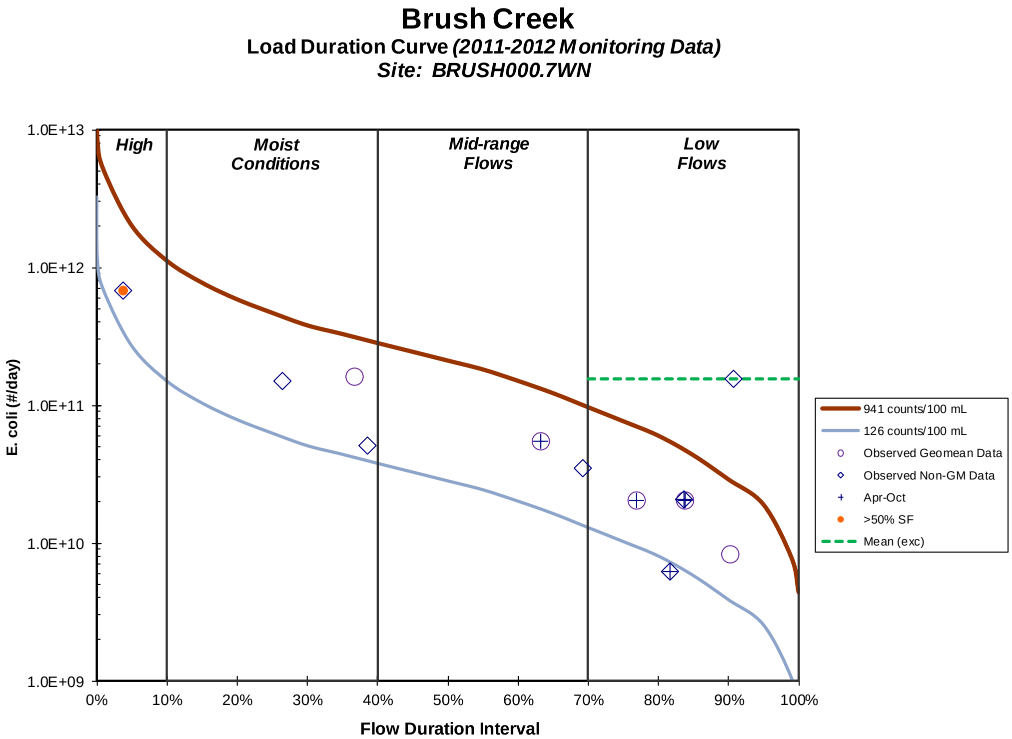

Figure E-9. E. Coli Load Duration Curve for Brush Creek – RM0.7

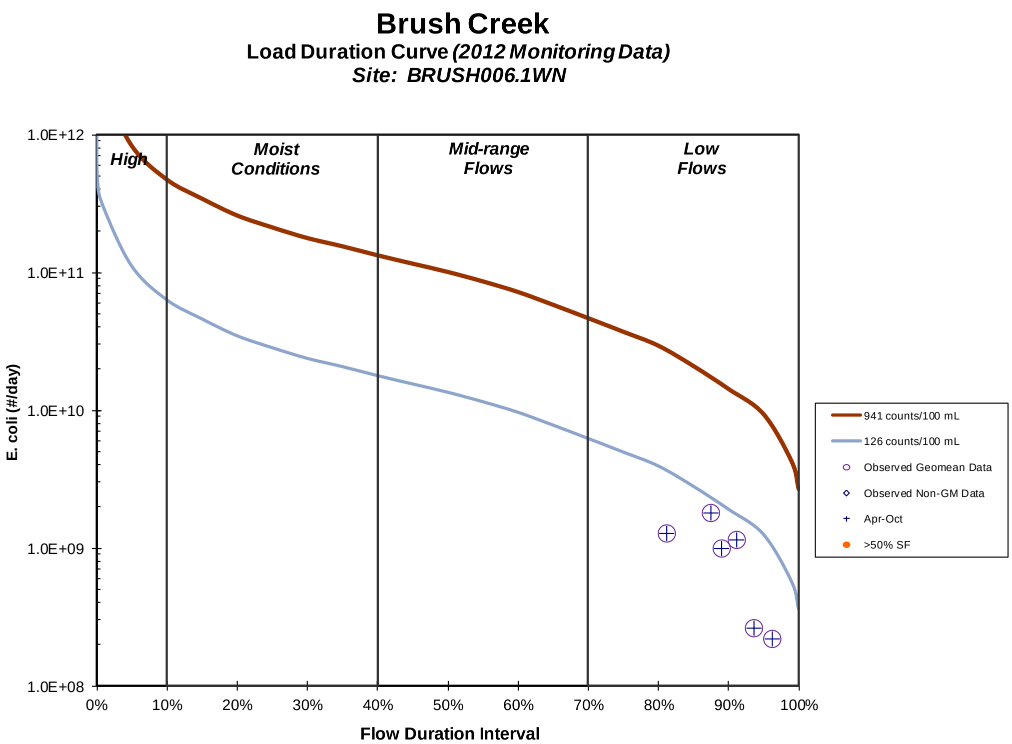

Figure E-10. E. Coli Load Duration Curve for Brush Creek – RM6.1

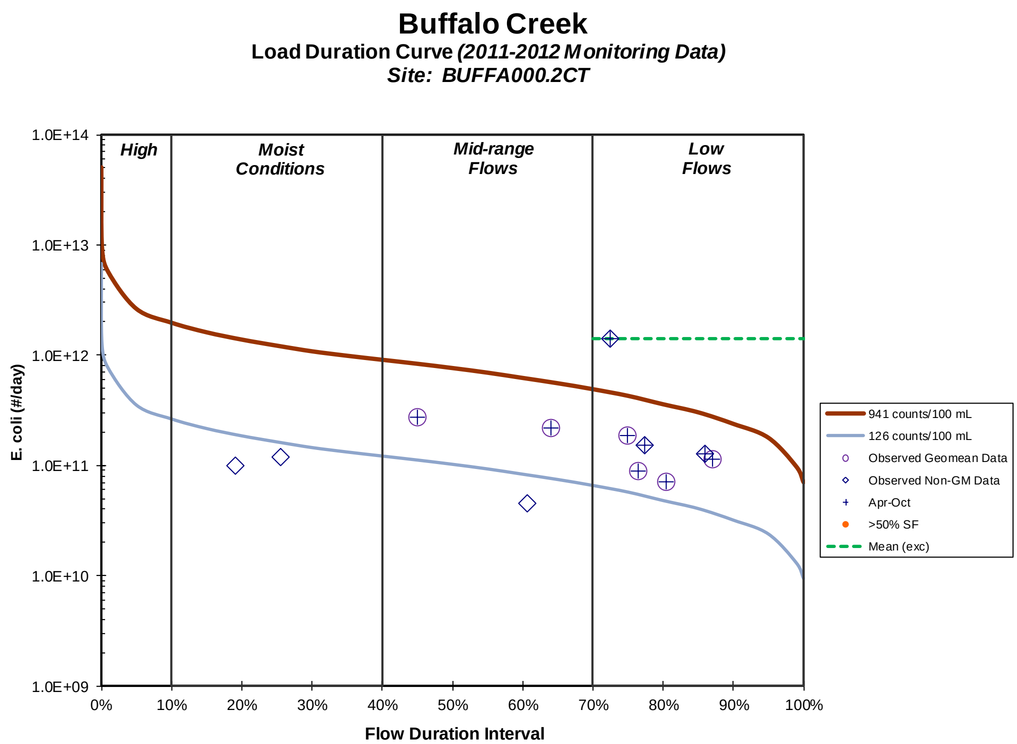

Figure E-11. E. Coli Load Duration Curve for Buffalo Creek – RM0.2

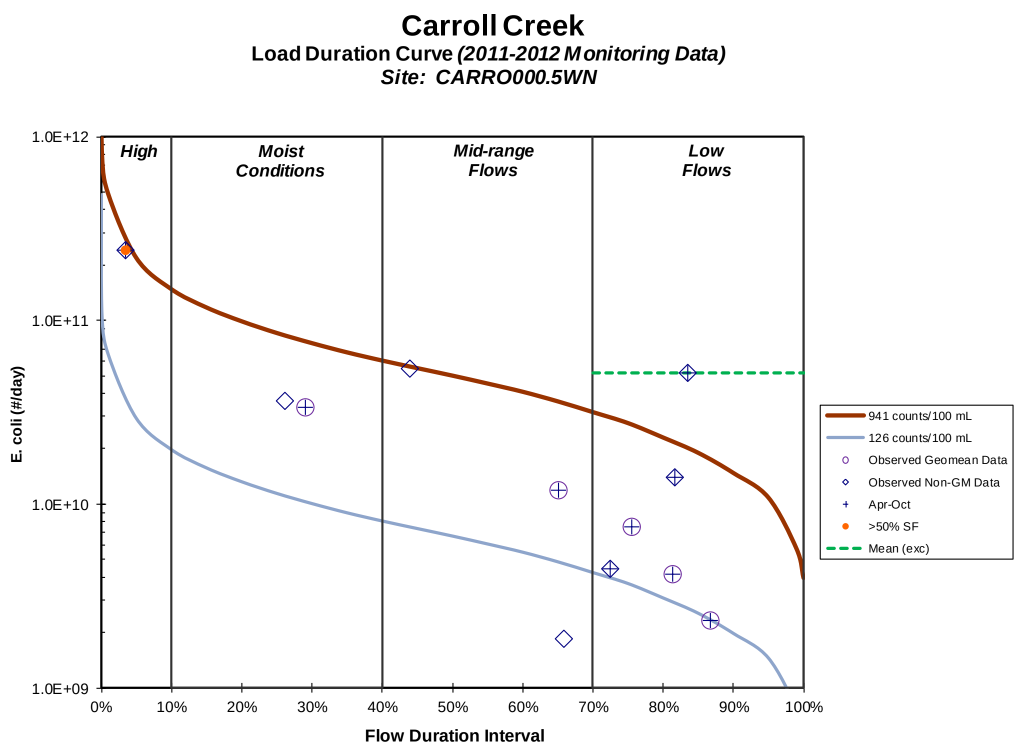

Figure E-12. E. Coli Load Duration Curve for Carroll Creek – RM0.5

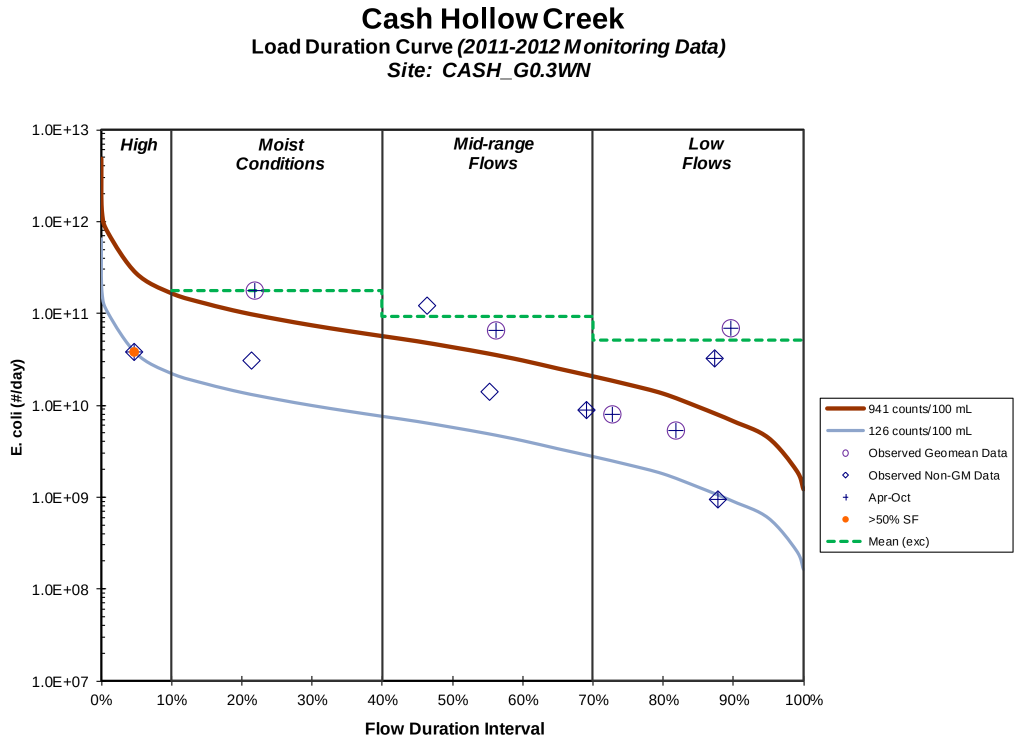

Figure E-13. E. Coli Load Duration Curve for Cash Hollow Creek – RM0.3

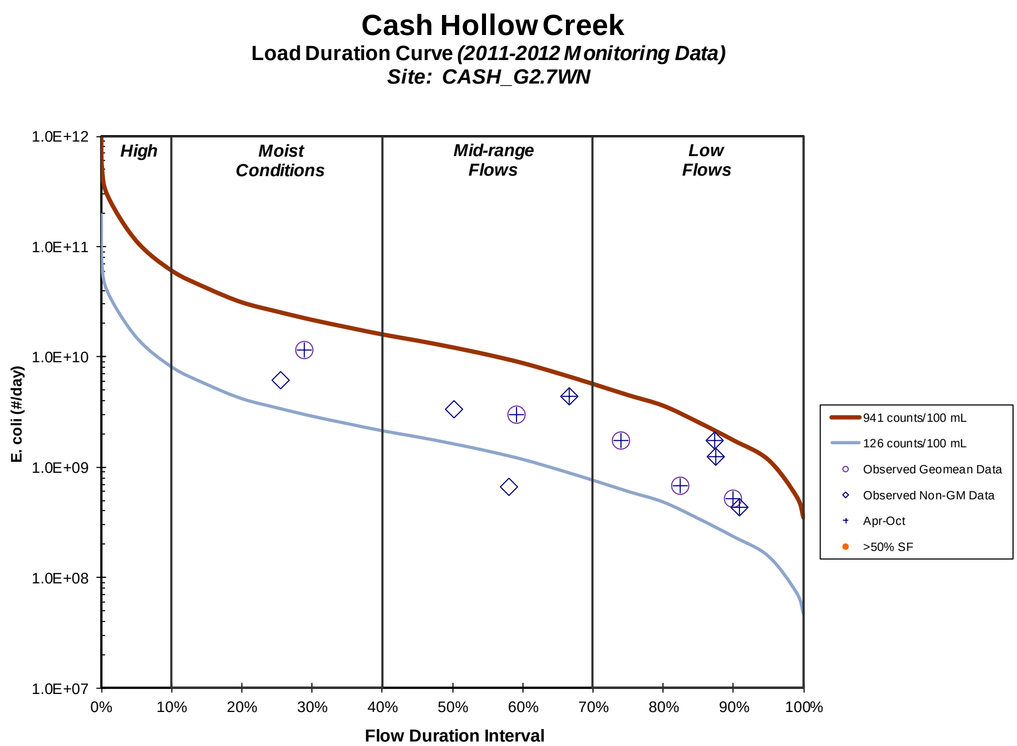

Figure E-14. E. Coli Load Duration Curve for Cash Hollow Creek – RM2.7

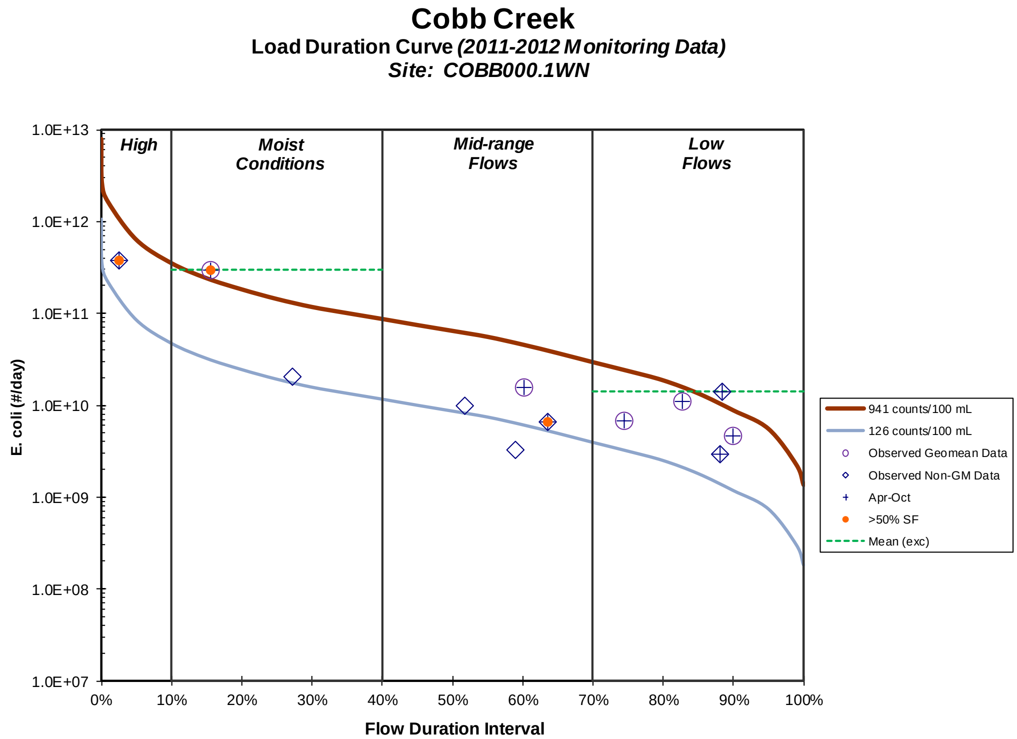

Figure E-15. E. Coli Load Duration Curve for Cobb Creek – RM0.1

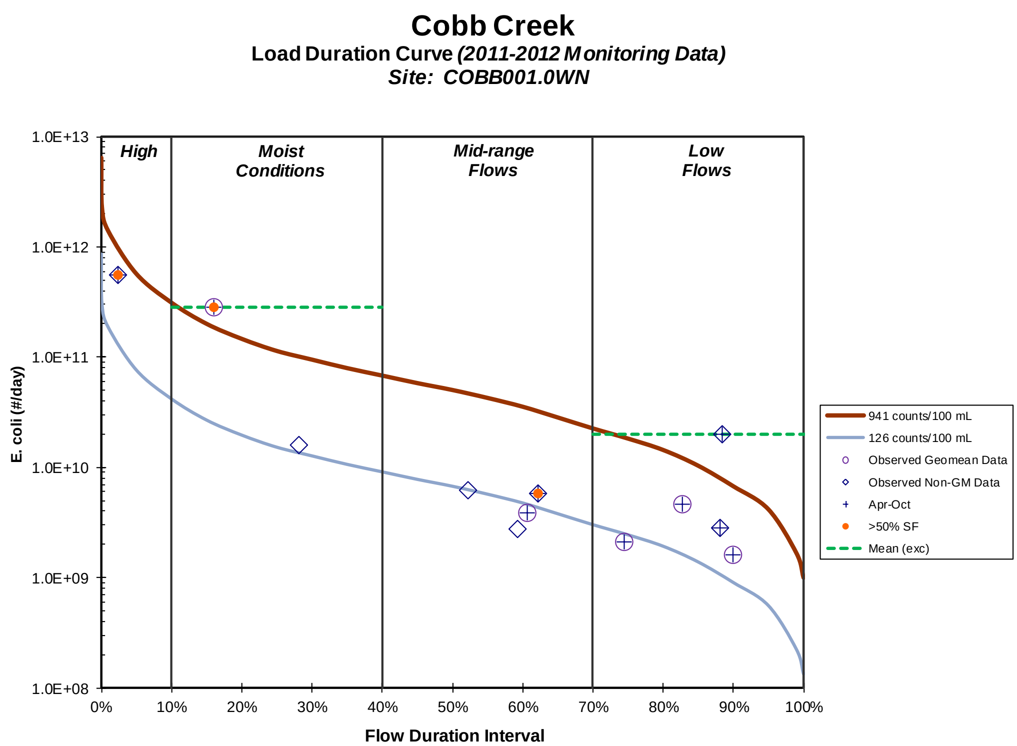

Figure E-16. E. Coli Load Duration Curve for Cobb Creek – RM1.0

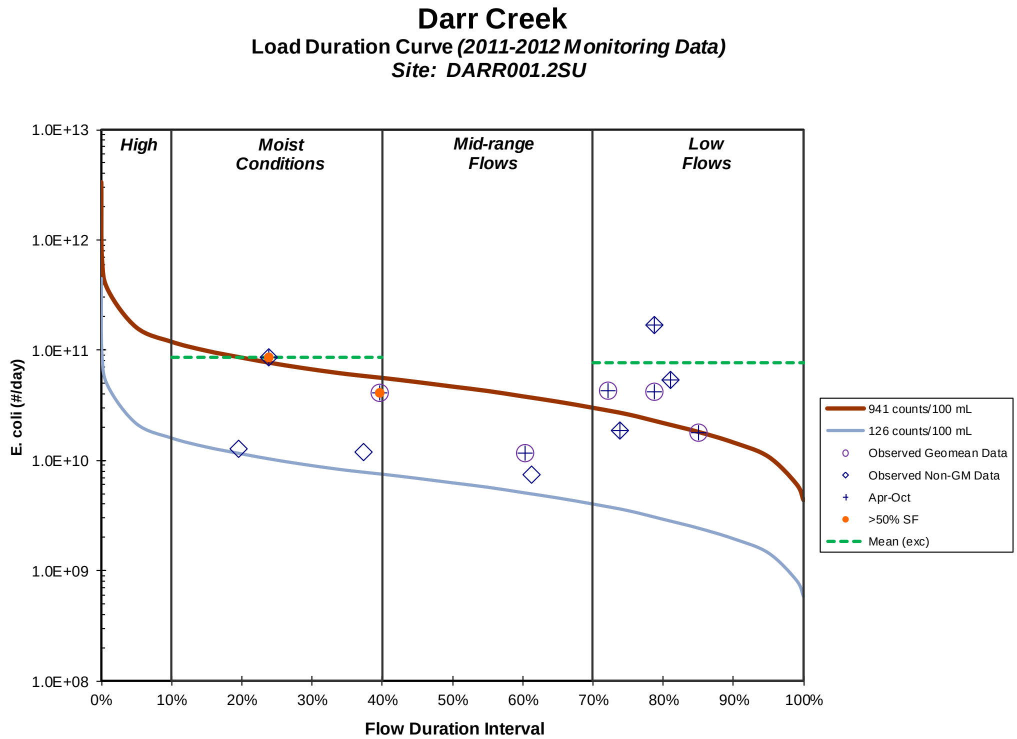

Figure E-17. E. Coli Load Duration Curve for Darr Creek – RM1.2

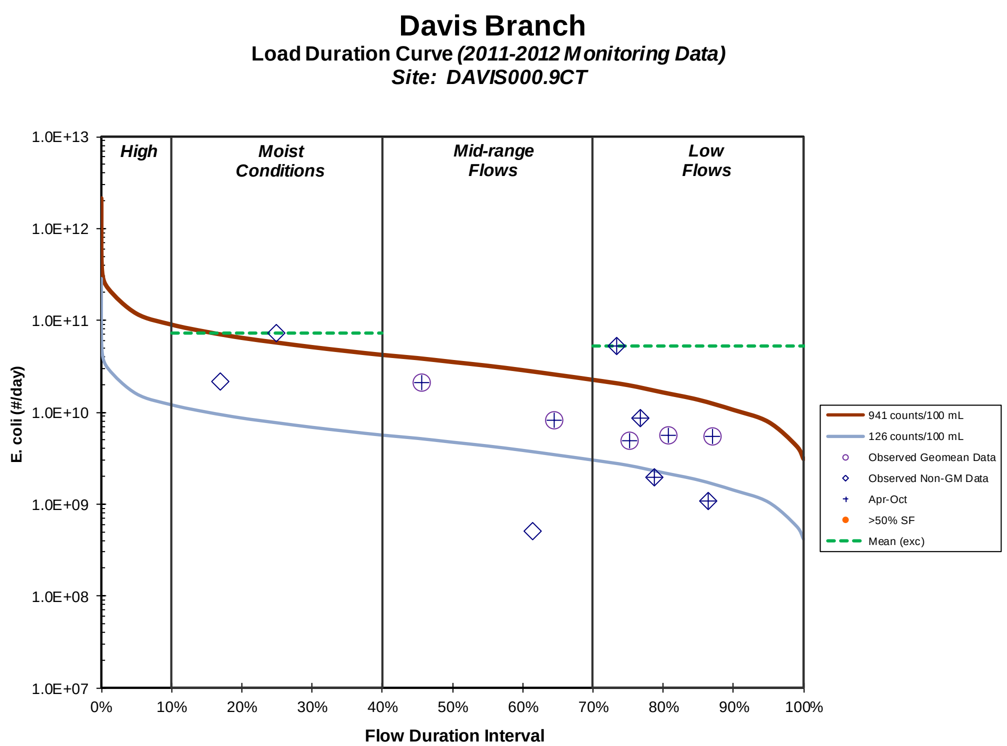

Figure E-18. E. Coli Load Duration Curve for Davis Branch – RM0.9

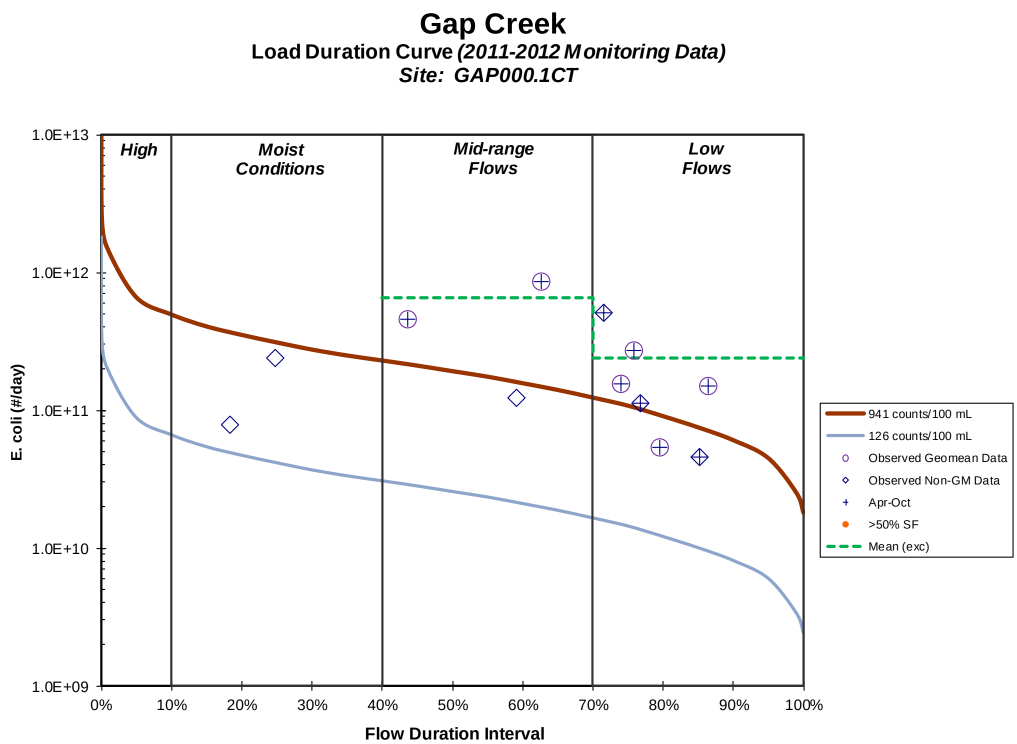

Figure E-19. E. Coli Load Duration Curve for Gap Creek – RM0.1

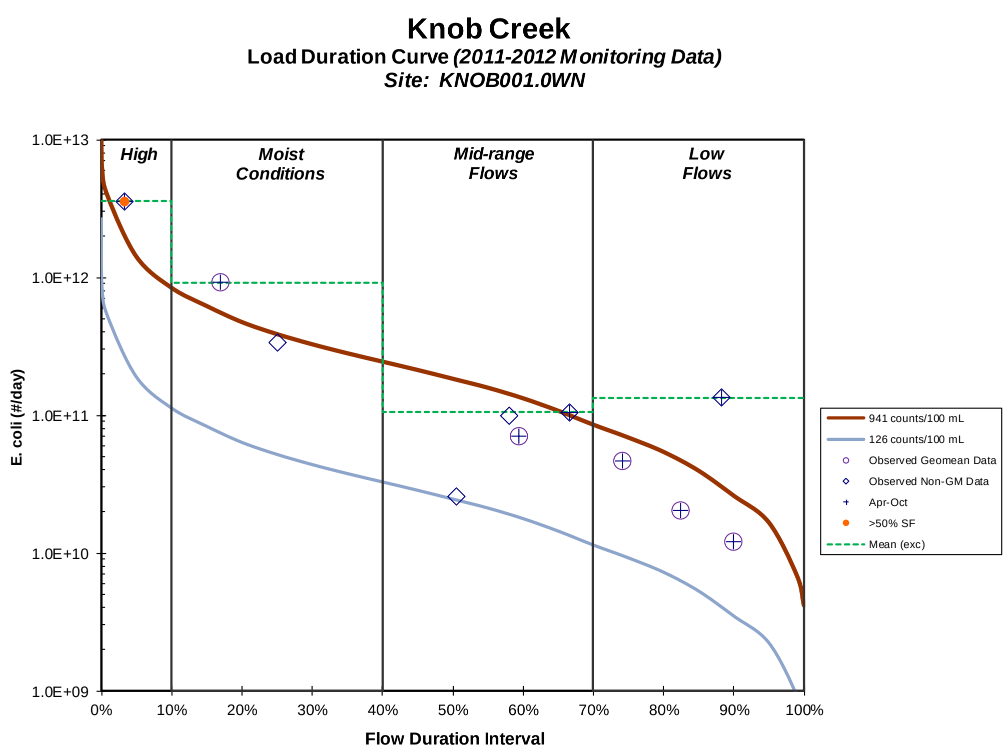

Figure E-20. E. Coli Load Duration Curve for Knob Creek – RM1.0

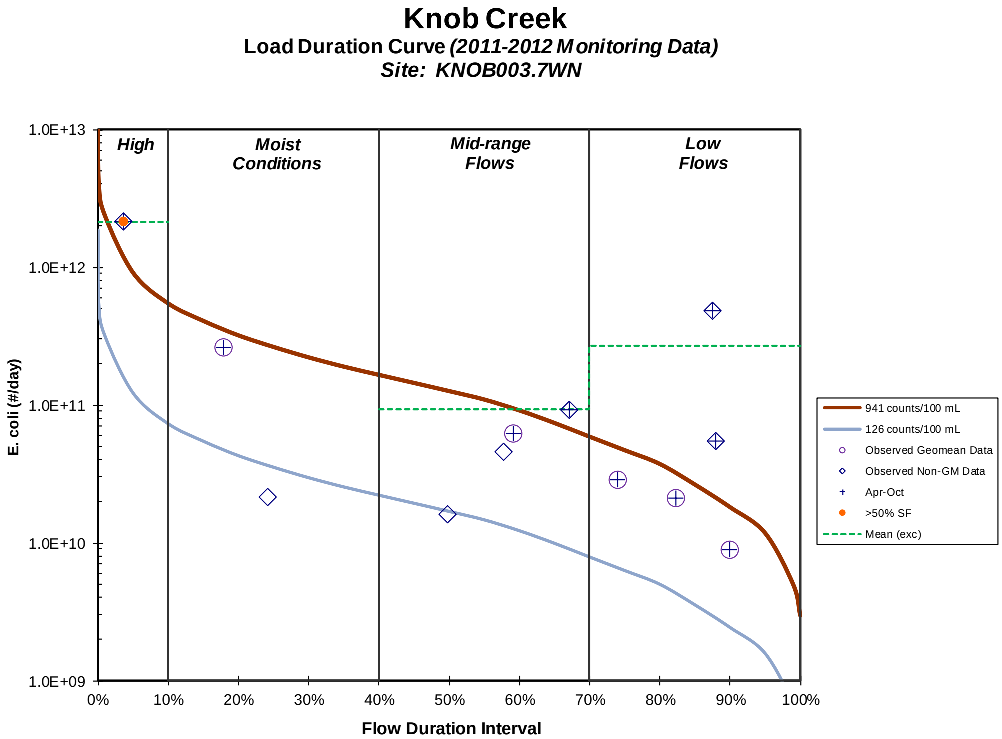

Figure E-21. E. Coli Load Duration Curve for Knob Creek – RM3.7

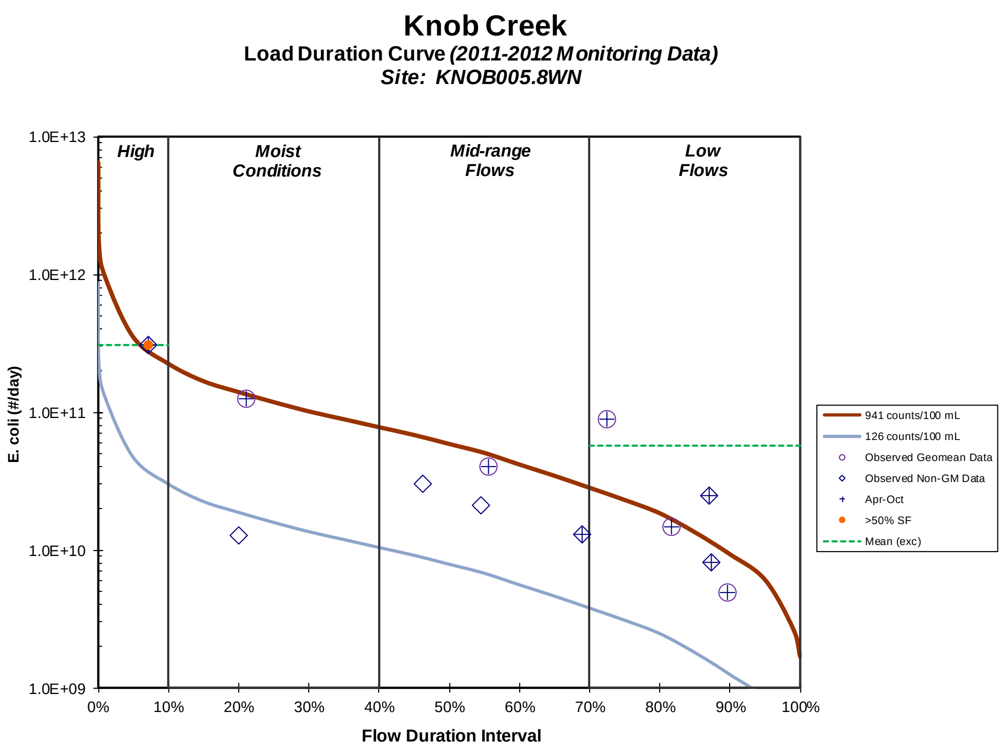

Figure E-22. E. Coli Load Duration Curve for Knob Creek– RM5.8

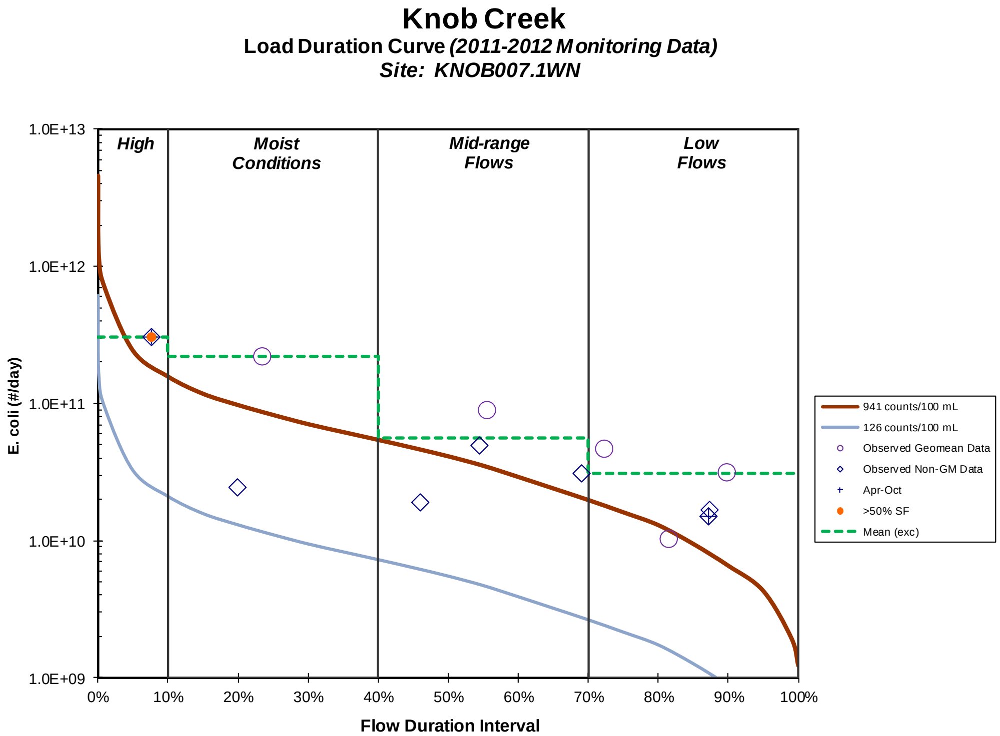

Figure E-23. E. Coli Load Duration Curve for Knob Creek – RM7.1

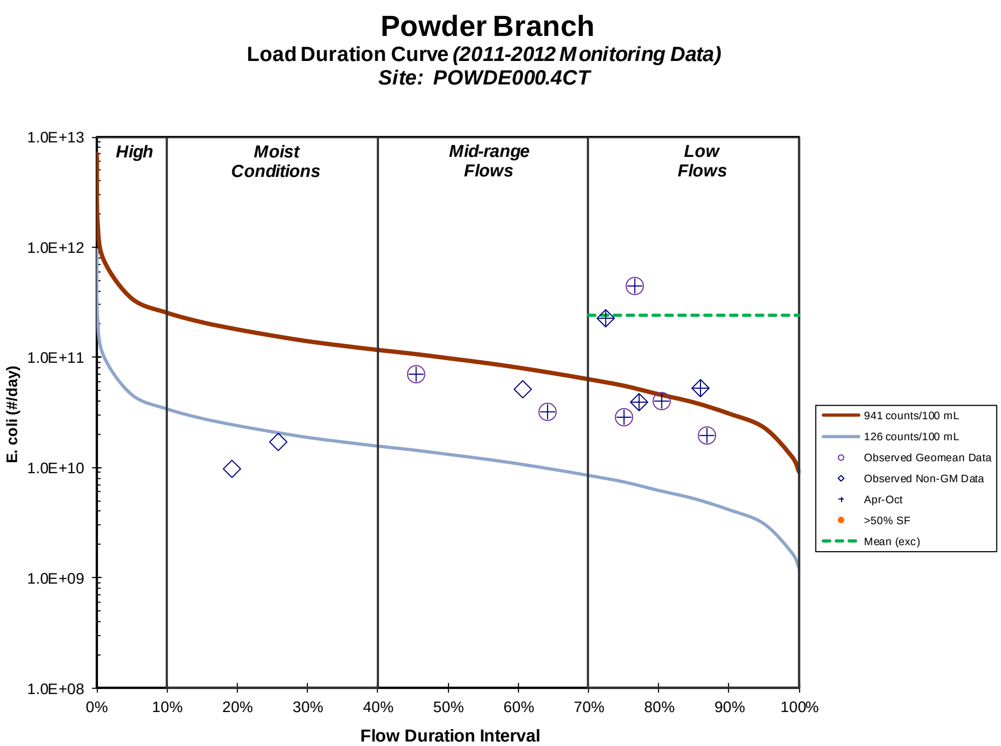

Figure E-24. E. Coli Load Duration Curve for Powder Branch – RM0.4

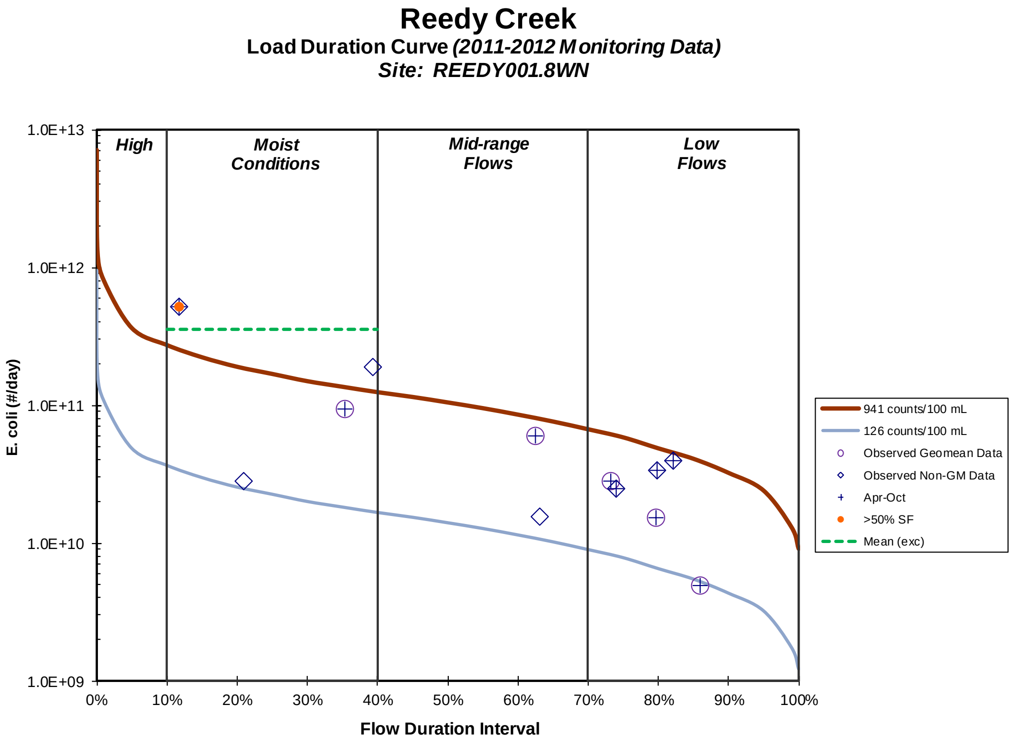

Figure E-25. E. Coli Load Duration Curve for Reedy Creek – RM1.8

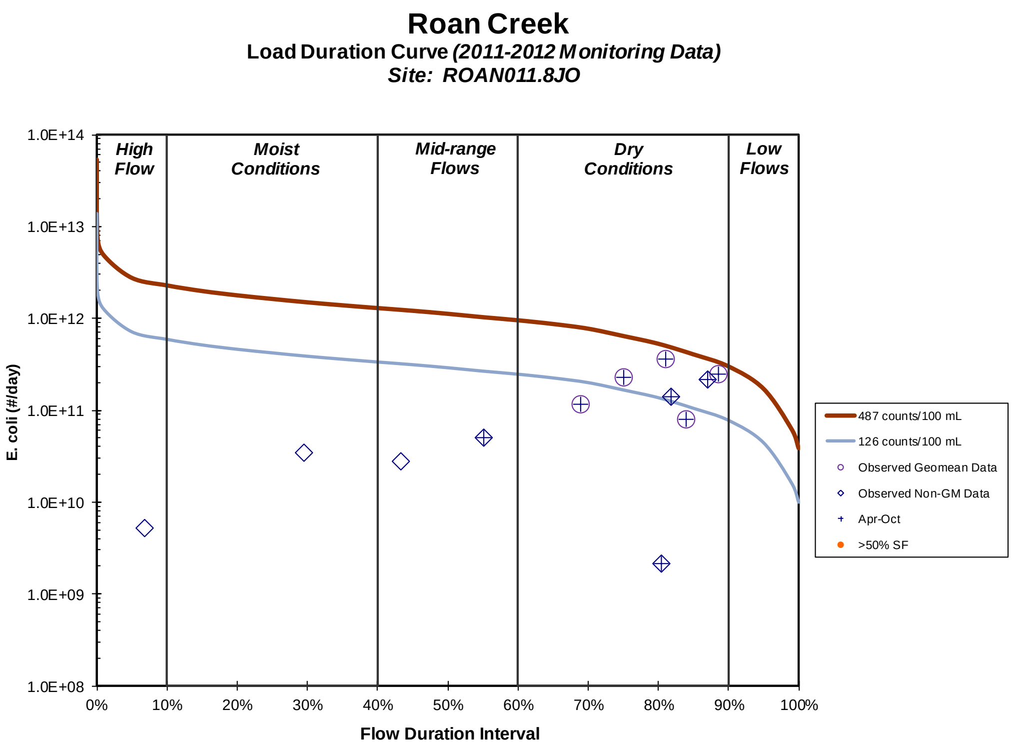

Figure E-26. E. Coli Load Duration Curve for Roan Creek – RM11.8

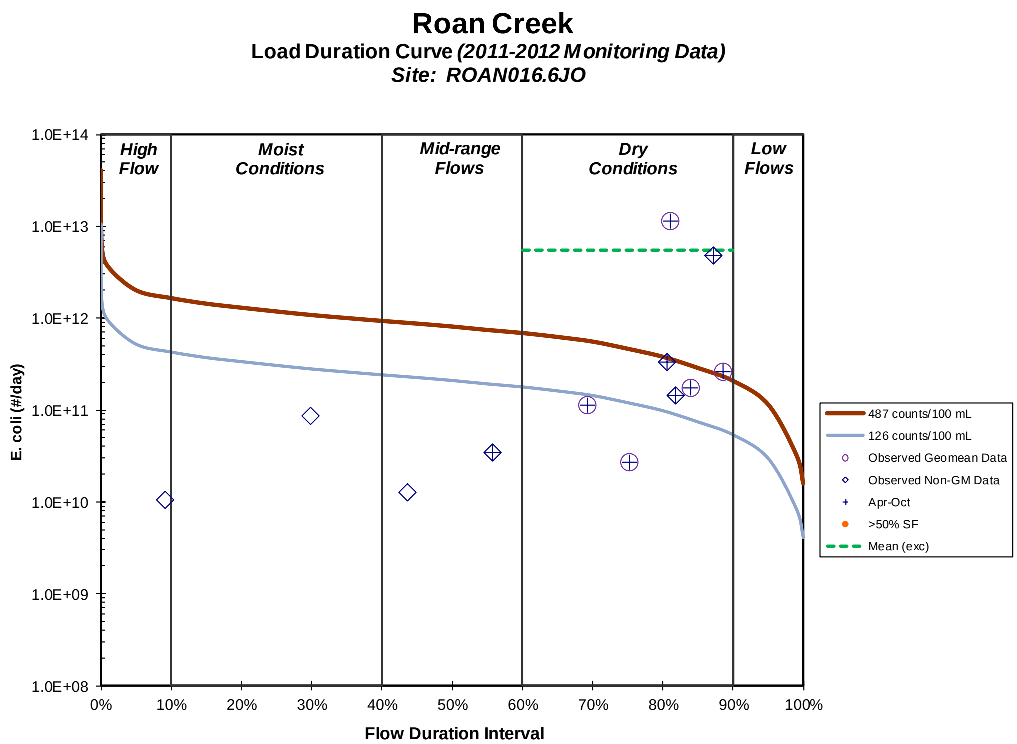

Figure E-27. E. Coli Load Duration Curve for Roan Creek – RM16.6

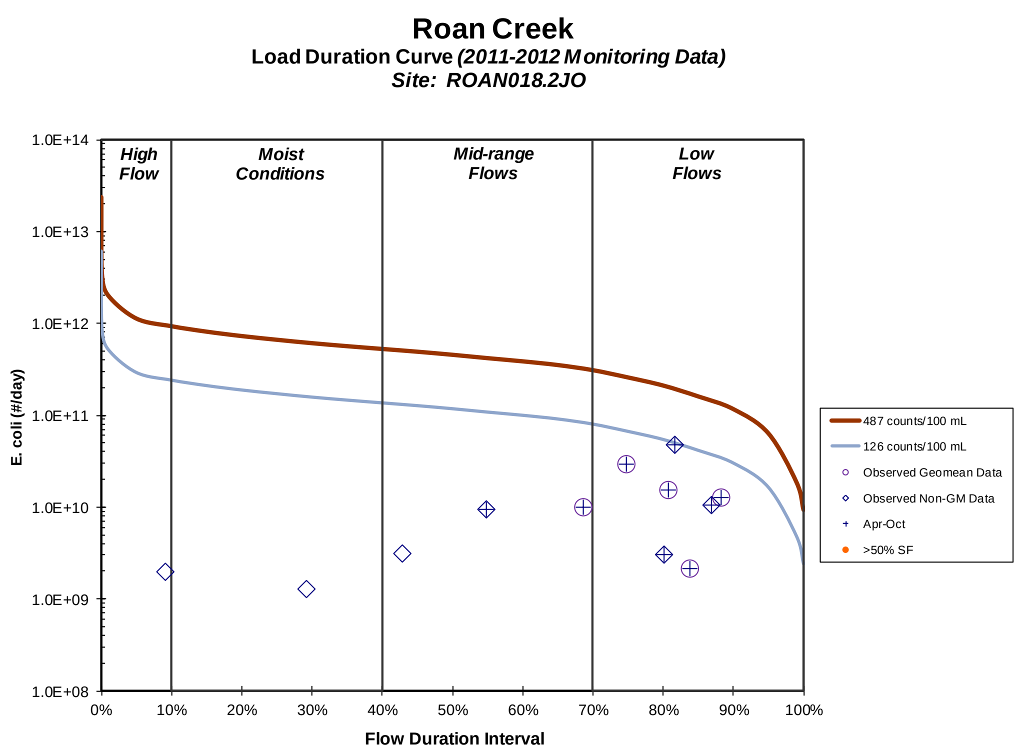

Figure E-28. E. Coli Load Duration Curve for Roan Creek – RM18.2

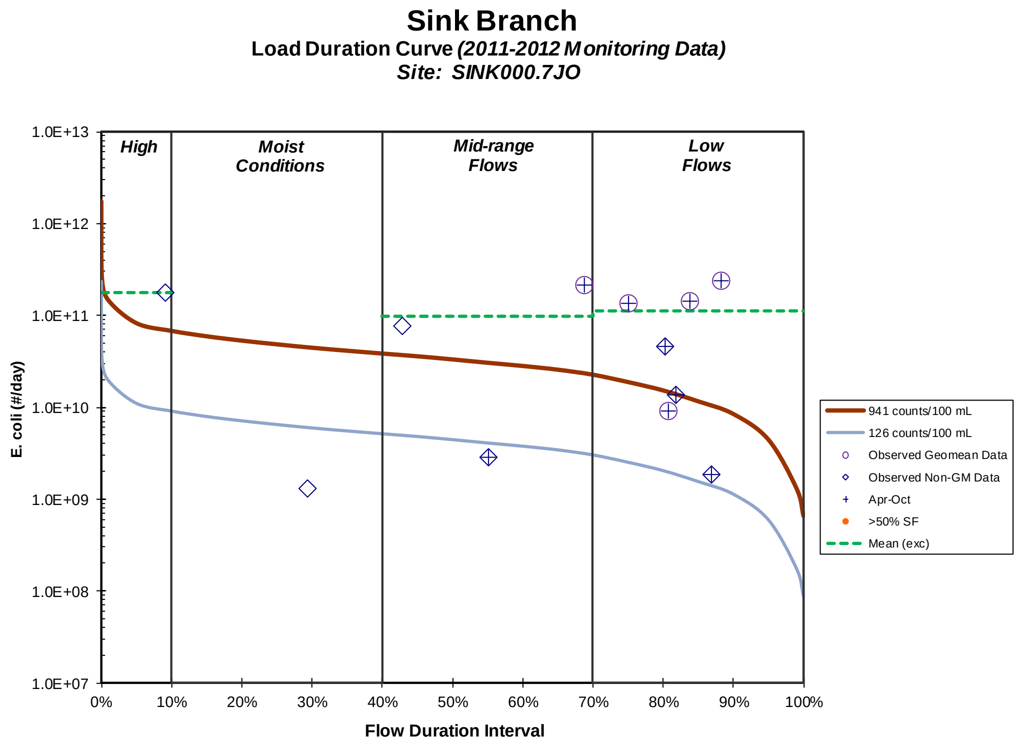

Figure E-29. E. Coli Load Duration Curve for Sink Branch – RM0.7

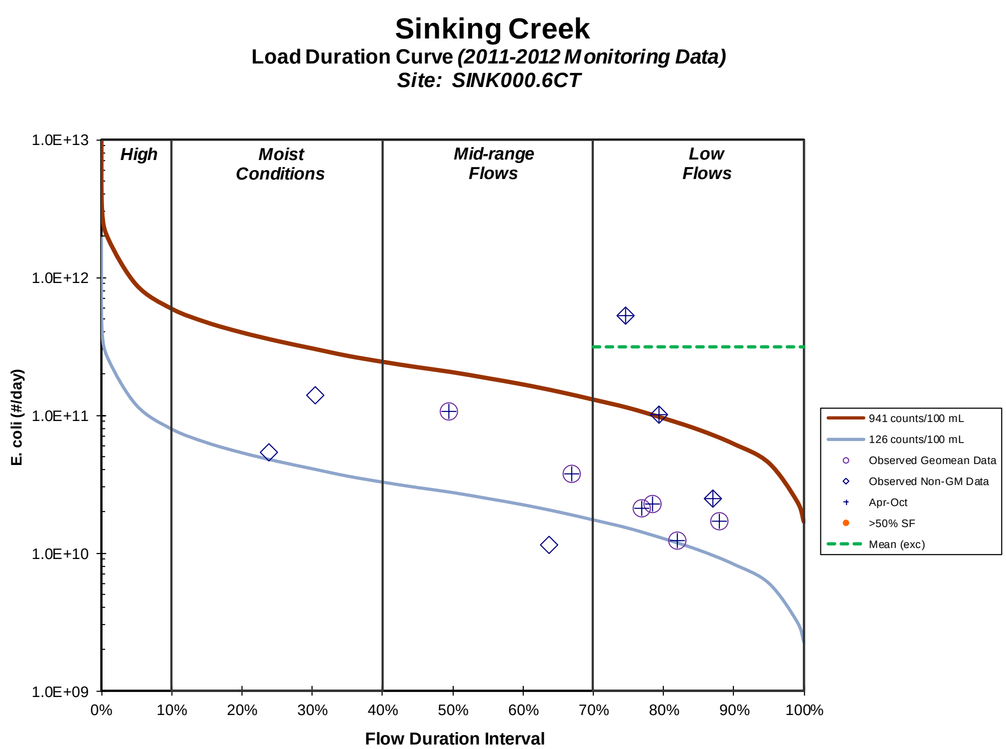

Figure E-30. E. Coli Load Duration Curve for Sinking Creek – RM0.6

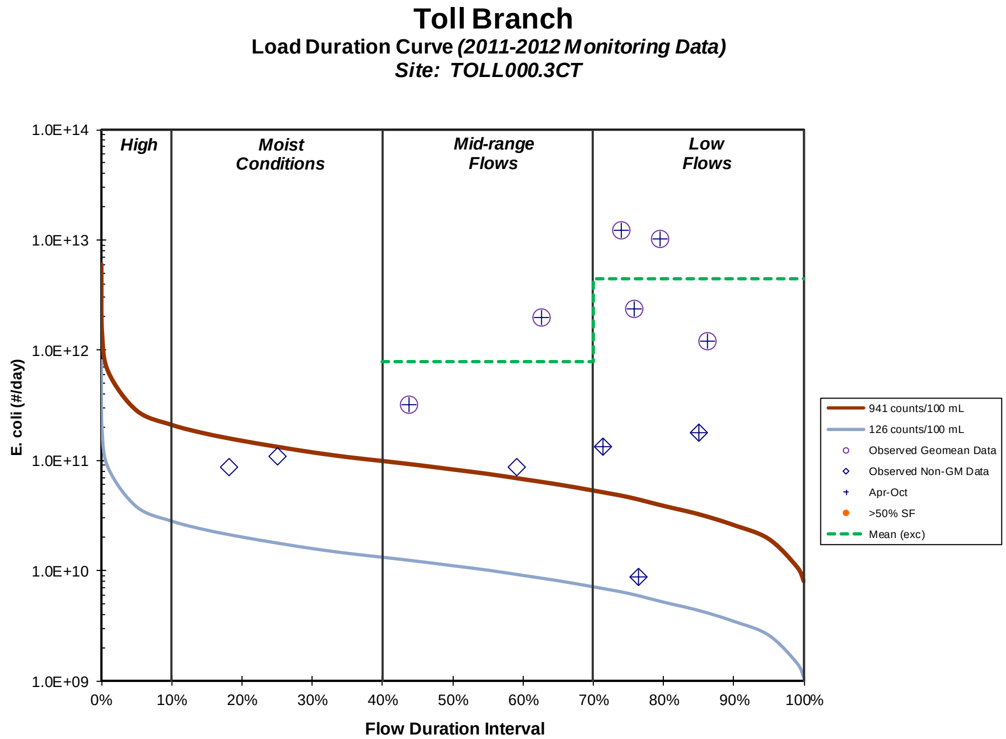

Figure E-31. E. Coli Load Duration Curve for Toll Branch – RM0.3

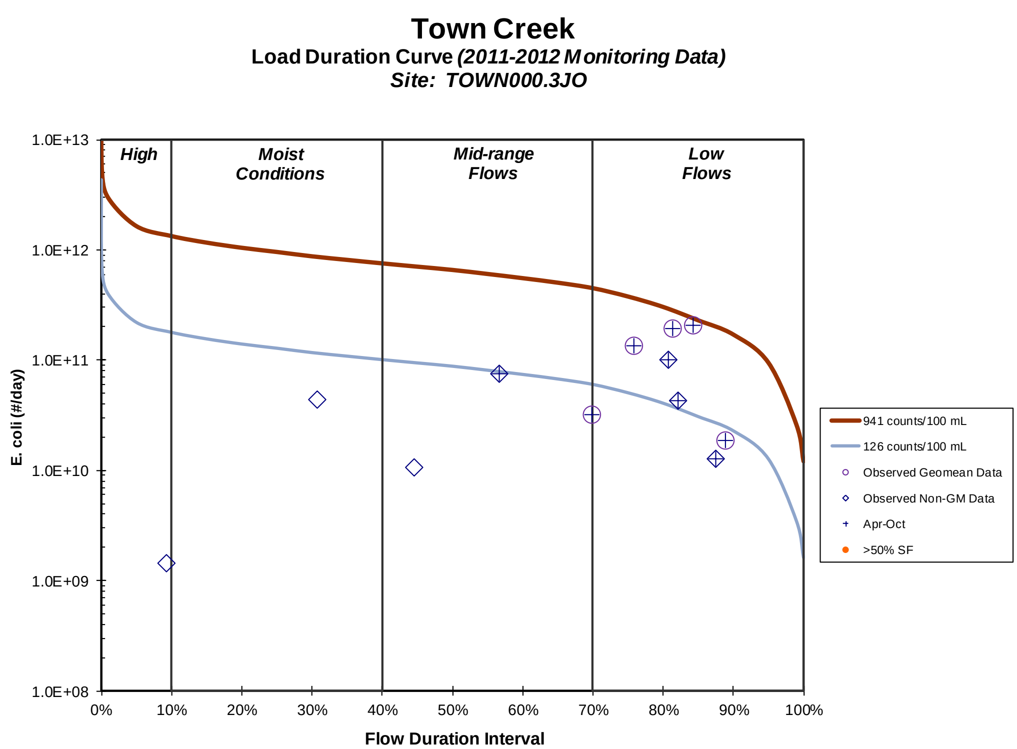

Figure E-32. E. Coli Load Duration Curve for Town Creek – RM0.3

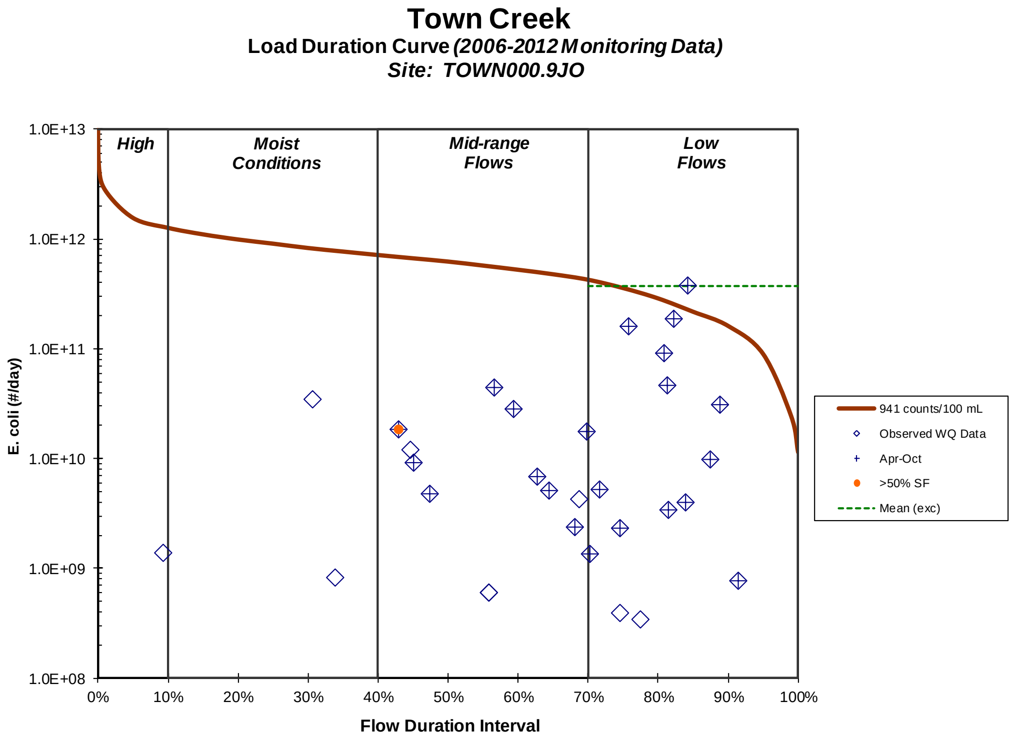

Figure E-33. E. Coli Load Duration Curve for Town Fork – RM0.9

Table E-4. Calculated Load Reduction Based on Daily Loading – Boones Creek – RM0.7

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/15/12	Moist Conditions	29.6	10.1%	46,110	3.33E+13	**98.0**		
1/17/12		20.0	21.6%	308	1.51E+11	NR		
9/7/11		16.7	29.3%	1986	8.13E+11	**52.6**	**75.3**	**77.8**
3/20/12	Mid-Range	13.5	40.2%	1203	3.98E+11	**21.8**		
9/14/11		8.77	62.8%	579	1.24E+11	NR		
11/2/11		8.50	64.1%	201	4.18E+10	NR	**21.8**	**29.6**
8/23/11	Low Flows	6.68	73.7%	1300	2.12E+11	**27.6**		
9/21/11		6.60	74.1%	1203	1.94E+11	**21.8**		
9/28/11		5.36	80.2%	816	1.07E+11	NR		
7/14/11		5.34	80.3%	7800	1.02E+12	**87.9**		
6/12/12		4.86	83.2%	2420	2.88E+11	**61.1**		
10/5/11		4.27	86.3%	1120	1.17E+11	**16.0**	**42.9**	**48.6**

Note: NR = No reduction required

Table E-5. Calculated Load Reduction Based on Geomean Data – Boones Creek – RM0.7

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction: to Target GM (126 CFU/100 mL)	Calculated Reduction: to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	16.7	29.3%	1986			
9/14/11	8.77	62.8%	579			
9/21/11	6.60	74.1%	1203			
9/28/11	5.36	80.2%	816			
10/5/11	4.27	86.3%	1120	**1048**	**88.0**	**89.2**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-6. Calculated Load Reduction Based on Daily Loading – Boones Creek – RM1.7

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/15/12	Moist Conditions	27.6	10.6%	32,550	2.20E+13	**97.1**		
1/17/12		19.5	21.4%	201	9.58E+10	NR		
9/7/11		16.3	28.9%	1733	6.91E+11	**45.7**		
3/20/12		13.2	40.0%	980	3.16E+11	**4.0**	**48.9**	**54.0**
9/14/11	Mid-Range	8.54	62.8%	1986	4.15E+11	**52.6**		
11/2/11		8.27	64.0%	276	5.58E+10	NR	**52.6**	**575.4**
8/23/11	Low Flows	6.48	73.8%	214	3.39E+10	NR		
9/21/11		6.42	74.0%	921	1.45E+11	NR		
7/14/11		5.20	80.2%	1203	1.53E+11	**21.8**		
9/28/11		5.22	80.2%	816	1.04E+11	NR		
6/12/12		4.73	83.1%	2420	2.80E+11	**61.1**		
10/5/11		4.15	86.3%	166	1.68E+10	NR	**41.4**	**47.3**

Note: NR = No reduction required

Table E-7. Calculated Load Reduction Based on Geomean Data – Boones Creek – RM1.7

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction	
					to Target GM (126 CFU/100 mL)	to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	16.3	28.9%	1733			
9/14/11	8.54	62.8%	1986			
9/21/11	6.42	74.0%	921			
9/28/11	5.22	80.2%	816			
10/5/11	4.15	86.3%	166	**844.4**	**85.1**	**86.6**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-8. Calculated Load Reduction Based on Daily Loading – Boones Creek – RM3.7

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/15/12	Moist Conditions	17.3	18.4%	38,730	1.64E+13	**97.6**		
1/17/12		16.5	20.0%	1046	4.22E+11	**10.0**		
9/7/11		12.3	32.7%	3280	9.85E+11	**71.3**		
3/20/12		11.1	38.2%	2420	6.57E+11	**61.1**	**60.0**	**64.0**
9/14/11	Mid-Range	7.18	61.5%	1986	3.49E+11	**52.6**		
11/2/11		6.95	62.9%	2420	4.12E+11	**61.1**	**56.9**	**61.2**
9/21/11	Low Flows	5.38	73.1%	2420	3.18E+11	**61.1**		
8/23/11		5.32	73.7%	1414	1.84E+11	**33.5**		
7/14/11		4.34	79.5%	8600	9.14E+11	**89.1**		
9/28/11		4.35	79.5%	727	7.74E+10	NR		
6/12/12		3.95	82.2%	2420	2.34E+11	**61.1**		
10/5/11		3.44	85.8%	2420	2.04E+11	**61.1**	**61.2**	**65.1**

Note: NR = No reduction required

Table E-9. Calculated Load Reduction Based on Geomean Data – Boones Creek – RM3.7

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction	
					to Target GM (126 CFU/100 mL)	to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	12.3	32.7%	3280			
9/14/11	7.18	61.5%	1986			
9/21/11	5.38	73.1%	2420			
9/28/11	4.35	79.5%	727			
10/5/11	3.44	85.8%	2420	**1943.6**	**93.5**	**94.2**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-10. Calculated Load Reduction Based on Daily Loading – Boones Creek – RM7.6

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/17/12	Moist Conditions	5.12	19.5%	1120	1.40E+11	**16.0**		
5/15/12		4.57	24.0%	9330	1.04E+12	**89.9**		
3/20/12		3.46	37.3%	4200	3.55E+11	**77.6**		
9/7/11		3.35	39.3%	2420	1.98E+11	**61.1**	**61.2**	**65.0**
9/14/11	Mid-Range	2.24	60.6%	3230	1.77E+11	**70.9**		
11/2/11		2.17	62.1%	649	3.45E+10	NR	**70.9**	**73.8**
9/21/11	Low Flows	1.68	72.4%	1553	6.38E+10	**39.4**		
8/23/11		1.64	73.4%	1300	5.21E+10	**27.6**		
7/14/11		1.35	79.0%	2420	8.02E+10	**61.1**		
9/28/11		1.36	79.0%	1414	4.70E+10	**33.5**		
6/12/12		1.23	81.6%	2880	8.69E+10	**67.3**		
10/5/11		1.08	85.3%	12,110	3.19E+11	**92.2**	**53.5**	**58.2**

Note: NR = No reduction required

Table E-11. Calculated Load Reduction Based on Geomean Data – Boones Creek – RM7.6

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	3.35	39.3%	2420			
9/14/11	2.24	60.6%	3230			
9/21/11	1.68	72.4%	1553			
9/28/11	1.36	79.0%	1414			
10/5/11	1.08	85.3%	12,110	**2908**	**95.7**	**96.1**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-12. Calculated Load Reduction Based on Daily Loading – Brush Creek – RM0.7

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/10/12	High Flows	106.97	3.8%	261	6.83E+11	NR	**NR**	**NR**
3/6/12	Moist Conditions	18.963	26.5%	326	1.51E+11	NR		
9/8/11		13.505	36.8%	488	1.61E+11	NR		
11/9/11		12.809	38.5%	162	5.08E+10	NR	**NR**	**NR**
9/15/11	Mid-Range	5.7759	63.2%	387	5.47E+10	NR		
8/17/11		4.3735	69.3%	326	3.49E+10	NR	**NR**	**NR**
9/22/11	Low Flows	3.0318	76.9%	276	2.05E+10	NR		
6/6/12		2.3608	81.7%	107	6.18E+09	NR		
5/8/12		2.062	83.7%	411	2.07E+10	NR		
9/29/11		2.0386	83.8%	411	2.05E+10	NR		
9/1/11		1.2378	90.3%	272	8.24E+09	NR		
7/12/11		1.184	90.7%	5370	1.56E+11	**82.5**	**82.5**	**84.2**

Note: NR = No reduction required

Table E-13. Calculated Load Reduction Based on Geomean Data – Brush Creek – RM0.7

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/1/11	1.24	90.3%	272			
9/8/11	13.5	36.8%	488			
9/15/11	5.78	63.2%	387			
9/22/11	3.03	76.9%	276			
9/29/11	2.04	83.8%	411	**357.3**	**64.7**	**68.4**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-14. Calculated Load Reduction Based on Daily Loading – Brush Creek – RM6.1

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
6/6/12	Low Flows	1.18	81.2%	44	1.28E+09	NR	**NR**	**NR**
6/12/12		0.762	87.5%	96	1.79E+09	NR		
6/14/12		0.666	89.1%	61	9.94E+08	NR		
5/29/12		0.568	91.2%	82	1.14E+09	NR		
5/31/12		0.466	93.6%	23	2.62E+08	NR		
6/20/12		0.330	96.3%	27	2.18E+08	NR		

Note: NR = No reduction required

Table E-15. Calculated Load Reduction Based on Geomean Data – Brush Creek – RM6.1

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
5/29/12	0.568	91.2%	82			
5/31/12	0.466	93.6%	23			
6/6/12	1.18	81.2%	44			
6/12/12	0.762	87.5%	96			
6/14/12	0.666	89.1%	61	**54.6**	**NR**	**NR**
6/20/12	0.330	96.3%	27	**48.6**	**NR**	**NR**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-16. Calculated Load Reduction Based on Daily Loading – Buffalo Creek – RM0.2

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
3/7/12	Moist-Conditions	61.8	19.1%	66	9.98E+10	NR		
1/11/12		52.3	25.6%	93	1.19E+11	NR	**NR**	**NR**
9/8/11	Mid-Range	36.3	45.0%	308	2.73E+11	NR		
11/1/11		26.6	60.7%	70	4.56E+10	NR		
9/15/11		24.7	64.1%	365	2.20E+11	NR	**NR**	**NR**
5/9/12	Low Flows	19.9	72.5%	2920	1.42E+12	**67.8**		
9/22/11		18.6	74.9%	411	1.87E+11	NR		
8/24/11		17.6	76.5%	206	8.87E+10	NR		
6/6/12		17.1	77.4%	365	1.53E+11	NR		
9/29/11		15.3	80.5%	190	7.13E+10	NR		
7/19/11		12.6	86.0%	411	1.26E+11	NR		
9/1/11		12.0	87.0%	387	1.13E+11	NR	**67.8**	**71.0**

Note: NR = No reduction required

Table E-17. Calculated Load Reduction Based on Geomean Data – Buffalo Creek – RM0.2

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction: to Target GM (126 CFU/100 mL)	Calculated Reduction: to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
8/24/11	17.6	76.5%	206			
9/1/11	12.0	87.0%	387			
9/8/11	36.3	45.0%	308			
9/15/11	24.7	64.1%	365			
9/22/11	18.6	74.9%	411	**326**	**64.1**	**65.3**
9/29/11	15.3	80.5%	190	**298**	**57.7**	**62.1**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-18. Calculated Load Reduction Based on Daily Loading – Carroll Creek – RM0.5

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/15/12	High Flows	11.4	3.5%	866	2.42E+11	NR	**NR**	**NR**
1/17/12	Moist-Conditions	3.61	26.1%	411	3.63E+10	NR		
9/7/11		3.35	29.1%	411	3.37E+10	NR	**NR**	**NR**
3/20/12	Mid-Range	2.43	44.0%	921	5.48E+10	NR		
9/14/11		1.57	65.1%	308	1.18E+10	NR		
11/2/11		1.53	65.9%	49	1.84E+09	NR	**NR**	**NR**
8/23/11	Low Flows	1.29	72.5%	140	4.42E+09	NR		
9/21/11		1.18	75.5%	261	7.53E+09	NR		
9/28/11		0.949	81.4%	179	4.16E+09	NR		
7/14/11		0.934	81.6%	613	1.40E+10	NR		
6/12/12		0.869	83.5%	2420	5.15E+10	**61.1**		
10/5/11		0.752	86.8%	127	2.34E+09	NR	**61.1**	**65.0**

Note: NR = No reduction required

Table E-19. Calculated Load Reduction Based on Geomean Data – Carroll Creek – RM0.5

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	3.35	29.1%	411			
9/14/11	1.57	65.1%	308			
9/21/11	1.18	75.5%	261			
9/28/11	0.949	81.4%	179			
10/5/11	0.752	86.8%	127	**237**	**46.9**	**52.4**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-20. Calculated Load Reduction Based on Daily Loading – Cash Hollow Creek – RM0.3

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/15/12	High Flows	12.2	4.7%	127	3.80E+10	NR	**NR**	**NR**
1/17/12	Moist-Conditions	4.27	21.4%	291	3.04E+10	NR		
9/7/11		4.21	21.9%	1733	1.79E+11	**45.7**	**45.7**	**51.1**
11/2/11	Mid-Range	2.05	46.4%	2420	1.21E+11	**61.1**		
3/20/12		1.58	55.3%	365	1.41E+10	NR		
9/14/11		1.53	56.2%	1733	6.49E+10	**45.7**		
8/23/11		0.932	69.1%	387	8.83E+09	NR	**53.4**	**58.1**
9/21/11	Low Flows	0.800	72.7%	411	8.05E+09	NR		
9/28/11		0.524	81.8%	411	5.27E+09	NR		
6/12/12		0.353	87.4%	3790	3.28E+10	**75.2**		
7/14/11		0.342	87.8%	114	9.54E+08	NR		
10/5/11		0.300	89.7%	9330	6.85E+10	**89.9**	**82.5**	**84.3**

Note: NR = No reduction required

Table E-21. Calculated Load Reduction Based on Geomean Data – Cash Hollow Creek – RM0.3

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	4.21	21.9%	1733			
9/14/11	1.53	56.2%	1733			
9/21/11	0.800	72.7%	411			
9/28/11	0.524	81.8%	411			
10/5/11	0.300	89.7%	9330	**1365**	**90.8**	**91.7**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-22. Calculated Load Reduction Based on Daily Loading – Cash Hollow Creek – RM2.7

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/17/12	Moist-Conditions	1.11	25.5%	228	6.17E+09	NR		
9/7/11		0.973	28.9%	488	1.16E+10	NR	**NR**	**NR**
11/2/11	Mid-Range	0.526	50.2%	261	3.36E+09	NR		
3/20/12		0.410	58.0%	66	6.61E+08	NR		
9/14/11		0.392	59.2%	308	2.96E+09	NR		
8/23/11		0.289	66.6%	613	4.34E+09	NR	**NR**	**NR**
9/21/11	Low Flows	0.206	74.0%	345	1.74E+09	NR		
9/28/11		0.135	82.4%	206	6.81E+08	NR		
6/12/12		0.093	87.4%	770	1.76E+09	NR		
7/14/11		0.092	87.5%	548	1.24E+09	NR		
10/5/11		0.077	89.9%	276	5.20E+08	NR		
6/15/12		0.071	90.9%	248	4.32E+08	NR	**NR**	**NR**

Note: NR = No reduction required

Table E-23. Calculated Load Reduction Based on Geomean Data – Cash Hollow Creek – RM2.7

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction	
					to Target GM (126 CFU/100 mL)	to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	0.973	28.9%	488			
9/14/11	0.392	59.2%	308			
9/21/11	0.206	74.0%	345			
9/28/11	0.135	82.4%	206			
10/5/11	0.077	89.9%	276	**312**	**59.6**	**63.8**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-24. Calculated Load Reduction Based on Daily Loading – Cobb Creek – RM0.1

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/15/12	High Flows	42.6	2.6%	365	3.80E+11	NR	**NR**	**NR**
9/7/11	Moist-Conditions	10.1	15.5%	1203	2.99E+11	**21.8**		
1/17/12		5.67	27.3%	146	2.02E+10	NR	**21.8**	**29.6**
11/2/11	Mid-Range	2.66	51.7%	153	9.96E+09	NR		
3/20/12		2.07	59.0%	65	3.29E+09	NR		
9/14/11		1.98	60.2%	326	1.58E+10	NR		
8/23/11		1.71	63.6%	157	6.56E+09	NR	**NR**	**NR**
9/21/11	Low Flows	1.06	74.4%	261	6.76E+09	NR		
9/28/11		0.683	82.7%	649	1.08E+10	NR		
7/14/11		0.458	88.1%	260	2.91E+09	NR		
6/12/12		0.445	88.4%	1300	1.41E+10	**27.6**		
10/5/11		0.383	90.0%	488	4.57E+09	NR	**27.6**	**34.8**

Note: NR = No reduction required

Table E-25. Calculated Load Reduction Based on Geomean Data – Cobb Creek – RM0.1

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	10.1	15.5%	1203			
9/14/11	1.98	60.2%	326			
9/21/11	1.06	74.4%	261			
9/28/11	0.683	82.7%	649			
10/5/11	0.383	90.0%	488	**504**	**75.0**	**77.6**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-26. Calculated Load Reduction Based on Daily Loading – Cobb Creek – RM1.0

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/15/12	High Flows	39.3	2.4%	579	5.57E+11	NR	**NR**	**NR**
9/7/11	Moist-Conditions	8.18	16.1%	1414	2.83E+11	**33.5**	**33.5**	**40.1**
1/17/12		4.36	28.2%	148	1.58E+10	NR		
11/2/11	Mid-Range	2.04	52.2%	124	6.18E+09	NR	**NR**	**NR**
3/20/12		1.58	59.3%	71	2.75E+09	NR		
9/14/11		1.51	60.6%	105	3.88E+09	NR		
8/23/11		1.42	62.2%	166	5.75E+09	NR		
9/21/11	Low Flows	0.814	74.4%	105	2.09E+09	NR	**61.1**	**65.0**
9/28/11		0.523	82.7%	365	4.67E+09	NR		
7/14/11		0.351	88.1%	326	2.80E+09	NR		
6/12/12		0.339	88.4%	2420	2.01E+10	**61.1**		
10/5/11		0.293	89.9%	225	1.61E+09	NR		

Note: NR = No reduction required

Table E-27. Calculated Load Reduction Based on Geomean Data – Cobb Creek – RM1.0

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	8.18	16.1%	1414			
9/14/11	1.51	60.6%	105			
9/21/11	0.814	74.4%	105			
9/28/11	0.523	82.7%	365			
10/5/11	0.293	89.9%	225	**264**	**52.3**	**57.3**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-28. Calculated Load Reduction Based on Daily Loading – Darr Creek – RM1.2

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/17/12	Moist-Conditions	3.74	19.6%	138	1.26E+10	NR		
5/15/12		3.38	23.8%	1046	8.64E+10	**10.0**		
3/20/12		2.53	37.4%	194	1.20E+10	NR		
9/7/11		2.44	39.7%	687	4.10E+10	NR	**10.0**	**19.0**
9/14/11	Mid-Range	1.65	60.4%	291	1.17E+10	NR		
11/2/11		1.61	61.3%	187	7.37E+09	NR	**NR**	**NR**
9/21/11	Low Flows	1.24	72.2%	1414	4.27E+10	**33.5**		
8/23/11		1.18	73.8%	649	1.88E+10	NR		
9/28/11		0.998	78.7%	1733	4.23E+10	**45.7**		
7/14/11		0.996	78.8%	6850	1.67E+11	**86.3**		
6/12/12		0.913	81.0%	2420	5.41E+10	**61.1**		
10/5/11		0.791	85.0%	921	1.78E+10	NR	**56.6**	**50.4**

Note: NR = No reduction required

Table E-29. Calculated Load Reduction Based on Geomean Data – Darr Creek – RM1.2

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	2.44	39.7%	687			
9/14/11	1.65	60.4%	291			
9/21/11	1.24	72.2%	1414			
9/28/11	0.998	78.7%	1733			
10/5/11	0.791	85.0%	921	**853**	**85.2**	**86.8**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-30. Calculated Load Reduction Based on Daily Loading – Davis Branch – RM0.9

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
3/7/12	Moist-Conditions	3.06	17.0%	285	2.13E+10	NR	21.8	29.6
1/11/12		2.50	24.9%	1203	7.35E+10	**21.8**		
9/8/11	Mid-Range	1.66	45.7%	517	2.10E+10	NR	NR	NR
11/1/11		1.21	61.5%	17	5.04E+08	NR		
9/15/11		1.13	64.5%	299	8.24E+09	NR		
5/9/12	Low Flows	0.894	73.4%	2420	5.30E+10	**61.1**	61.1	65.0
9/22/11		0.851	75.2%	236	4.91E+09	NR		
8/24/11		0.805	76.8%	435	8.57E+09	NR		
6/6/12		0.750	78.7%	108	1.98E+09	NR		
9/29/11		0.695	80.7%	328	5.57E+09	NR		
7/19/11		0.549	86.5%	80	1.07E+09	NR		
9/1/11		0.538	87.0%	411	5.41E+09	NR		

Note: NR = No reduction required

Table E-31. Calculated Load Reduction Based on Geomean Data – Davis Branch – RM0.9

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/1/11	0.538	87.0%	411			
9/8/11	1.66	45.7%	517			
9/15/11	1.13	64.5%	299			
9/22/11	0.851	75.2%	236			
9/29/11	0.695	80.7%	328	**345**	**63.5**	**67.3**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-32. Calculated Load Reduction Based on Daily Loading – Gap Creek – RM0.1

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
3/7/12	Moist-Conditions	16.1	18.3%	201	7.89E+10	NR		
1/11/12		13.6	24.8%	727	2.41E+11	NR	**NR**	**NR**
9/8/11	Mid-Range	9.40	43.7%	1986	4.57E+11	**52.6**		
11/1/11		6.94	59.1%	727	1.23E+11	NR		
9/15/11		6.42	62.7%	5460	8.58E+11	**82.8**	**67.7**	**70.9**
5/9/12	Low Flows	5.18	71.6%	4040	5.12E+11	**76.7**		
9/22/11		4.85	74.0%	1300	1.54E+11	**27.6**		
8/24/11		4.56	75.8%	2420	2.70E+11	**61.1**		
6/6/12		4.42	76.7%	1046	1.13E+11	**10.0**		
9/29/11		3.99	79.5%	548	5.35E+10	NR		
7/19/11		3.25	85.2%	579	4.60E+10	NR		
9/1/11		3.10	86.4%	1986	1.50E+11	**52.6**	**45.6**	**51.1**

Note: NR = No reduction required

Table E-33. Calculated Load Reduction Based on Geomean Data – Gap Creek – RM0.1

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction	
					to Target GM (126 CFU/100 mL)	to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
8/24/11	4.56	75.8%	2420			
9/1/11	3.10	86.4%	1986			
9/8/11	9.40	43.7%	1986			
9/15/11	6.42	62.7%	5460			
9/22/11	4.85	74.0%	1300	**2324**	**94.6**	**95.1**
9/29/11	3.99	79.5%	548	**1827**	**93.1**	**93.8**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-34. Calculated Load Reduction Based on Daily Loading – Knob Creek – RM1.0

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/15/12	High Flows	83.9	3.3%	1733	3.56E+12	**45.7**	**45.7**	**51.1**
9/7/11	Moist-Conditions	24.2	17.0%	1553	9.20E+11	**39.4**		
1/17/12		16.8	25.0%	816	3.36E+11	NR	**39.4**	**45.5**
11/2/11	Mid-Range	7.88	50.6%	133	2.56E+10	NR		
3/20/12		6.21	58.0%	649	9.86E+10	NR		
9/14/11		5.90	59.5%	488	7.04E+10	NR		
8/23/11		4.39	66.7%	980	1.05E+11	**4.0**	**4.0**	**13.6**
9/21/11	Low Flows	3.10	74.2%	613	4.64E+10	NR		
9/28/11		2.02	82.5%	411	2.03E+10	NR		
6/12/12		1.32	88.3%	4140	1.34E+11	**77.3**		
10/5/11		1.13	90.0%	435	1.21E+10	NR	**77.3**	**79.5**

Note: NR = No reduction required

Table E-35. Calculated Load Reduction Based on Geomean Data – Knob Creek – RM1.0

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	24.2	17.0%	1553			
9/14/11	5.90	59.5%	488			
9/21/11	3.10	74.2%	613			
9/28/11	2.02	82.5%	411			
10/5/11	1.13	90.0%	435	**608**	**79.3**	**81.4**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-36. Calculated Load Reduction Based on Daily Loading – Knob Creek – RM3.7

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/15/12	High Flows	50.5	3.6%	1733	2.14E+12	**45.7**	**45.7**	**51.1**
9/7/11	Moist-Conditions	15.5	17.9%	687	2.60E+11	NR		
1/17/12		11.8	24.2%	74	2.13E+10	NR	**NR**	**NR**
11/2/11	Mid-Range	5.51	49.8%	120	1.62E+10	NR		
3/20/12		4.31	57.7%	435	4.59E+10	NR		
9/14/11		4.12	59.1%	613	6.17E+10	NR		
8/23/11		2.92	67.1%	1300	9.29E+10	**27.6**	**27.6**	**34.8**
9/21/11	Low Flows	2.15	74.0%	548	2.88E+10	NR		
9/28/11		1.41	82.3%	613	2.11E+10	NR		
6/12/12		0.957	87.5%	20,640	4.83E+11	**95.4**		
7/14/11		0.922	87.9%	2420	5.46E+10	**61.1**		
10/5/11		0.789	90.0%	461	8.90E+09	NR	**78.3**	**80.4**

Note: NR = No reduction required

Table E-37. Calculated Load Reduction Based on Geomean Data – Knob Creek – RM3.7

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	15.5	17.9%	687			
9/14/11	4.12	59.1%	613			
9/21/11	2.15	74.0%	548			
9/28/11	1.41	82.3%	613			
10/5/11	0.789	90.0%	461	**579**	**78.2**	**80.5**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-38. Calculated Load Reduction Based on Daily Loading – Knob Creek – RM5.8

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/15/12	High Flows	12.0	7.2%	1046	3.07E+11	**10.1**	**10.1**	**19.0**
1/17/12	Moist-Conditions	6.08	20.0%	86	1.28E+10	NR		
9/7/11		5.88	21.1%	866	1.25E+11	NR	**NR**	**2.2**
11/2/11	Mid-Range	2.86	46.2%	435	3.04E+10	NR		
3/20/12		2.23	54.6%	387	2.11E+10	NR		
9/14/11		2.14	55.6%	770	4.03E+10	NR		
8/23/11		1.28	69.0%	411	1.29E+10	**27.6**	**27.6**	**34.8**
9/21/11	Low Flows	1.12	72.4%	3270	8.93E+10	**71.2**		
9/28/11		0.733	81.6%	816	1.46E+10	NR		
6/12/12		0.504	87.1%	2024	2.49E+10	**53.5**		
7/14/11		0.487	87.4%	687	8.18E+09	NR		
10/5/11		0.412	89.7%	488	4.92E+09	NR	**62.4**	**66.1**

Note: NR = No reduction required

Table E-39. Calculated Load Reduction Based on Geomean Data – Knob Creek – RM5.8

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	5.88	21.1%	866			
9/14/11	2.14	55.6%	770			
9/21/11	1.12	72.4%	3270			
9/28/11	0.733	81.6%	816			
10/5/11	0.412	89.7%	488	**972**	**87.0**	**88.4**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-40. Calculated Load Reduction Based on Daily Loading – Knob Creek – RM7.1

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/15/12	High Flows	8.09	7.6%	1553	3.07E+11	**39.4**	**39.4**	**45.5**
1/17/12	Moist-Conditions	4.25	19.9%	236	2.46E+10	NR		
9/7/11		3.74	23.5%	2420	2.22E+11	**61.1**	**61.1**	**65.0**
11/2/11	Mid-Range	2.00	46.0%	387	1.90E+10	NR		
3/20/12		1.55	54.5%	1300	4.93E+10	**27.6**		
9/14/11		1.50	55.5%	2420	8.88E+10	**61.1**		
8/23/11		0.889	69.1%	1414	3.08E+10	**33.5**	**40.7**	**46.6**
9/21/11	Low Flows	0.783	72.2%	2420	4.64E+10	**61.1**		
9/28/11		0.517	81.5%	816	1.03E+10	NR		
6/12/12		0.355	87.1%	1733	1.50E+10	**45.7**		
7/14/11		0.345	87.3%	1986	1.68E+10	**52.6**		
10/5/11		0.291	89.8%	4410	3.14E+10	**78.7**	**59.5**	**80.8**

Note: NR = No reduction required

Table E-41. Calculated Load Reduction Based on Geomean Data – Knob Creek – RM7.1

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction	
					to Target GM (126 CFU/100 mL)	to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	3.74	23.5%	2420			
9/14/11	1.50	55.5%	2420			
9/21/11	0.783	72.2%	2420			
9/28/11	0.517	81.5%	816			
10/5/11	0.291	89.8%	4410	**2195**	**94.3**	**94.9**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-42. Calculated Load Reduction Based on Daily Loading – Powder Branch – RM0.4

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
3/7/12	Moist-Conditions	7.97	19.2%	50	9.75E+09	NR		
1/11/12		6.71	25.8%	104	1.71E+10	NR	**NR**	**NR**
9/8/11	Mid-Range	4.65	45.5%	613	6.98E+10	NR		
11/1/11		3.44	60.7%	613	5.16E+10	NR		
9/15/11		3.19	64.2%	411	3.21E+10	NR	**NR**	**NR**
5/9/12	Low Flows	2.58	72.4%	3590	2.26E+11	**73.8**		
9/22/11		2.40	75.1%	488	2.87E+10	NR		
8/24/11		2.29	76.6%	7940	4.44E+11	**88.1**		
6/6/12		2.22	77.3%	727	3.95E+10	NR		
9/29/11		1.99	80.4%	816	3.97E+10	NR		
7/19/11		1.63	85.9%	1300	5.19E+10	**27.6**		
9/1/11		1.55	86.9%	517	1.97E+10	NR	**63.2**	**66.9**

Note: NR = No reduction required

Table E-43. Calculated Load Reduction Based on Geomean Data – Powder Branch – RM0.4

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
8/24/11	2.29	76.6%	7940			
9/1/11	1.55	86.9%	517			
9/8/11	4.65	45.5%	613			
9/15/11	3.19	64.2%	411			
9/22/11	2.40	75.1%	488	**872**	**85.6**	**87.0**
9/29/11	1.99	80.4%	816	**553**	**77.2**	**79.6**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-44. Calculated Load Reduction Based on Daily Loading – Reedy Creek – RM1.8

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/15/12	Moist-Conditions	10.8	11.8%	1986	5.23E+11	**52.6**		
1/17/12		8.09	20.9%	141	2.79E+10	NR		
9/7/11		5.86	35.3%	649	9.31E+10	NR		
3/20/12		5.47	39.4%	1414	1.89E+11	**33.5**	**43.0**	**48.7**
9/14/11	Mid-Range	3.53	62.5%	687	5.94E+10	NR		
11/2/11		3.46	63.1%	184	1.56E+10	NR	**NR**	**NR**
9/21/11	Low Flows	2.66	73.3%	435	2.83E+10	NR		
8/23/11		2.62	74.0%	387	2.48E+10	NR		
9/28/11		2.14	79.7%	291	1.52E+10	NR		
7/14/11		2.13	79.9%	649	3.37E+10	NR		
6/12/12		1.97	82.2%	816	3.93E+10	NR		
10/5/11		1.70	85.9%	119	4.94E+09	NR	**NR**	**NR**

Note: NR = No reduction required

Table E-45. Calculated Load Reduction Based on Geomean Data – Reedy Creek – RM1.8

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/7/11	5.86	35.3%	649			
9/14/11	3.53	62.5%	687			
9/21/11	2.66	73.3%	435			
9/28/11	2.14	79.7%	291			
10/5/11	1.70	85.9%	119	**368**	**65.7**	**69.3**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-46. Calculated Load Reduction Based on Daily Loading – Roan Creek – RM11.8

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/19/12	High Flows	212.6	6.9%	1	5.20E+09	NR	**NR**	**NR**
3/21/12	Moist-Conditions	126.6	29.5%	11	3.41E+10	NR	**NR**	**NR**
11/8/11	Mid-Range	103.5	43.3%	11	2.79E+10	NR		
5/22/12		86.3	55.2%	24	5.07E+10	NR	**NR**	**NR**
9/13/11	Dry Conditions	66.7	68.9%	71	1.16E+11	NR		
9/20/11		54.0	75.0%	173	2.29E+11	NR		
6/20/12		43.7	80.4%	2	2.14E+09	NR		
9/27/11		42.3	81.0%	344	3.56E+11	NR		
7/21/11		40.6	81.9%	141	1.40E+11	NR		
10/4/11		36.2	83.9%	89	7.88E+10	NR		
8/30/11		30.3	87.1%	291	2.16E+11	NR		
10/11/11		27.7	88.6%	365	2.47E+11	NR	**NR**	**NR**

Note: NR = No reduction required

Table E-47. Calculated Load Reduction Based on Geomean Data – Roan Creek – RM11.8

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction	
					to Target GM (126 CFU/100 mL)	to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/13/11	66.7	68.9%	71			
9/20/11	54.0	75.0%	173			
9/27/11	42.3	81.0%	344			
10/4/11	36.2	83.9%	89			
10/11/11	27.7	88.6%	365	**169**	**25.4**	**33.1**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-48. Calculated Load Reduction Based on Daily Loading – Roan Creek – RM16.6

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/19/12	High Flows	142.2	9.2%	3	1.04E+10	NR	**NR**	**NR**
3/21/12	Moist-Conditions	91.1	29.8%	39	8.69E+10	NR	**NR**	**NR**
11/8/11	Mid-Range	74.3	43.6%	7	1.27E+10	NR		
5/22/12		61.8	55.8%	23	3.48E+10	NR	**NR**	**NR**
9/13/11	Dry Conditions	47.6	69.3%	96	1.12E+11	NR		
9/20/11		38.4	75.3%	29	2.72E+10	NR		
6/20/12		30.8	80.6%	437	3.29E+11	NR		
9/27/11		29.8	81.1%	15530	1.13E+13	**96.9**		
7/21/11		28.5	81.9%	206	1.44E+11	NR		
10/4/11		25.4	84.0%	284	1.76E+11	NR		
8/30/11		21.1	87.2%	9340	4.83E+12	**94.8**		
10/11/11		19.2	88.6%	549	2.58E+11	**11.3**	**67.6**	**70.9**

Note: NR = No reduction required

Table E-49. Calculated Load Reduction Based on Geomean Data – Roan Creek – RM16.6

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction	
					to Target GM (126 CFU/100 mL)	to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/13/11	47.6	69.3%	96			
9/20/11	38.4	75.3%	29			
9/27/11	29.8	81.1%	15530			
10/4/11	25.4	84.0%	284			
10/11/11	19.2	88.6%	549	**368**	**65.8**	**69.3**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-50. Calculated Load Reduction Based on Daily Loading – Roan Creek – RM18.2

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/19/12	High Flows	80.4	9.2%	1	1.97E+09	NR	**NR**	**NR**
3/21/12	Moist-Conditions	51.8	29.2%	1	1.27E+09	NR	**NR**	**NR**
11/8/11	Mid-Range	42.3	42.9%	3	3.11E+09	NR		
5/22/12		35.2	54.9%	11	9.47E+09	NR		
9/13/11		27.1	68.7%	15	9.94E+09	NR	**NR**	**NR**
9/20/11	Low Flows	21.8	74.8%	55	2.94E+10	NR		
6/20/12		17.5	80.2%	7	3.00E+09	NR		
9/27/11		17.0	80.8%	37	1.54E+10	NR		
7/21/11		16.2	81.7%	119	4.73E+10	NR		
10/4/11		14.4	83.8%	6	2.12E+09	NR		
8/30/11		12.0	86.9%	36	1.06E+10	NR		
10/11/11		10.9	88.3%	47	1.25E+10	NR	**NR**	**NR**

Note: NR = No reduction required

Table E-51. Calculated Load Reduction Based on Geomean Data – Roan Creek – RM18.2

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/13/11	27.1	68.7%	15			
9/20/11	21.8	74.8%	55			
9/27/11	17.0	80.8%	37			
10/4/11	14.4	83.8%	6			
10/11/11	10.9	88.3%	47	**24.4**	**NR**	**NR**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-52. Calculated Load Reduction Based on Daily Loading – Sink Branch – RM0.7

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/19/12	High Flows	3.03	9.2%	2420	1.79E+11	**61.1**	**61.1**	**65.0**
3/21/12	Moist-Conditions	1.95	29.3%	27	1.29E+09	NR	**NR**	**NR**
11/8/11	Mid-Range	1.60	42.9%	1986	7.76E+10	**52.6**		
5/22/12		1.32	55.1%	87	2.82E+09	NR		
9/13/11		1.02	68.8%	8570	2.14E+11	**89.0**	**70.8**	**73.7**
9/20/11	Low Flows	0.821	75.0%	6770	1.36E+11	**86.1**		
6/20/12		0.653	80.3%	2850	4.56E+10	**67.0**		
9/27/11		0.640	80.7%	579	9.07E+09	NR		
7/21/11		0.602	81.8%	921	1.36E+10	NR		
10/4/11		0.541	83.8%	10860	1.44E+11	**91.3**		
8/30/11		0.447	86.9%	167	1.83E+09	NR		
10/11/11		0.409	88.3%	23820	2.38E+11	**96.0**	**85.1**	**70.9**

Note: NR = No reduction required

Table E-53. Calculated Load Reduction Based on Geomean Data – Sink Branch – RM0.7

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/13/11	1.02	68.8%	8570			
9/20/11	0.821	75.0%	6770			
9/27/11	0.640	80.7%	579			
10/4/11	0.541	83.8%	10860			
10/11/11	0.409	88.3%	23820	**6135**	**97.9**	**98.2**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-54. Calculated Load Reduction Based on Daily Loading – Sinking Creek – RM0.6

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
3/7/12	Moist-Conditions	15.4	23.9%	142	5.35E+10	NR		
1/11/12		13.1	30.5%	435	1.39E+11	NR	**NR**	**NR**
9/8/11	Mid-Range	8.99	49.4%	488	1.07E+11	NR		
11/1/11		6.61	63.8%	71	1.15E+10	NR		
9/15/11		6.11	66.9%	249	3.72E+10	NR	**NR**	**NR**
5/9/12	Low Flows	4.97	74.6%	4320	5.25E+11	**78.2**		
9/22/11		4.63	76.9%	186	2.11E+10	NR		
8/24/11		4.38	78.5%	210	2.25E+10	NR		
6/6/12		4.24	79.3%	980	1.02E+11	**4.0**		
9/29/11		3.80	82.0%	133	1.24E+10	NR		
7/19/11		3.10	87.1%	326	2.47E+10	NR		
9/1/11		2.97	88.0%	236	1.72E+10	NR	**41.1**	**47.0**

Note: NR = No reduction required

Table E-55. Calculated Load Reduction Based on Geomean Data – Sinking Creek – RM0.6

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
8/24/11	4.38	78.5%	210			
9/1/11	2.97	88.0%	236			
9/8/11	8.99	49.4%	488			
9/15/11	6.11	66.9%	249			
9/22/11	4.63	76.9%	186	**257**	**51.0**	**56.0**
9/29/11	3.80	82.0%	133	**230**	**45.3**	**50.9**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-56. Calculated Load Reduction Based on Daily Loading – Toll Branch – RM0.3

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
3/7/12	Moist-Conditions	6.89	18.2%	517	8.71E+10	NR		
1/11/12		5.79	25.0%	770	1.09E+11	NR	**NR**	**NR**
9/8/11	Mid-Range	4.03	43.8%	3230	3.19E+11	**70.9**		
11/1/11		2.98	59.1%	1203	8.76E+10	**21.8**		
9/15/11		2.77	62.7%	29,090	1.97E+12	**96.8**	**63.1**	**66.8**
5/9/12	Low Flows	2.23	71.4%	2420	1.32E+11	**61.1**		
9/22/11		2.08	74.0%	241,960	1.23E+13	**99.6**		
8/24/11		1.98	75.8%	48,840	2.36E+12	**98.1**		
6/6/12		1.92	76.5%	187	8.78E+09	NR		
9/29/11		1.72	79.5%	241,960	1.02E+13	**99.6**		
7/19/11		1.41	85.0%	5120	1.77E+11	**81.6**		
9/1/11		1.34	86.2%	36,540	1.20E+12	**97.4**	**89.6**	**90.6**

Note: NR = No reduction required

Table E-57. Calculated Load Reduction Based on Geomean Data – Toll Branch – RM0.3

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
8/24/11	1.98	75.8%	48,840			
9/1/11	1.34	86.2%	36,540			
9/8/11	4.03	43.8%	3230			
9/15/11	2.77	62.7%	29,090			
9/22/11	2.08	74.0%	241,960	**33,239**	**99.6**	**99.7**
9/29/11	1.72	79.5%	241,960	**46,27.**	**99.7**	**99.8**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-58. Calculated Load Reduction Based on Daily Loading – Town Creek – RM0.3

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/19/12	High Flows	59.2	9.3%	1	1.45E+09	NR	**NR**	**NR**
3/21/12	Moist-Conditions	37.7	30.7%	47	4.33E+10	NR	**NR**	**NR**
11/8/11	Mid-Range	30.7	44.6%	14	NR	NR		
5/22/12		25.6	56.6%	119	7.44E+10	NR		
9/13/11		19.6	69.8%	66	3.17E+10	NR	**NR**	**NR**
9/20/11	Low Flows	15.8	75.8%	345	1.34E+11	NR		
6/20/12		12.7	80.8%	326	1.01E+11	NR		
9/27/11		12.3	81.3%	649	1.95E+11	NR		
7/21/11		11.7	82.2%	148	4.25E+10	NR		
10/4/11		10.4	84.3%	816	2.08E+11	NR		
8/30/11		8.74	87.5%	59	1.26E+10	NR		
10/11/11		7.96	88.9%	96	1.87E+10	NR	**NR**	**NR**

Note: NR = No reduction required

Table E-59. Calculated Load Reduction Based on Geomean Data – Town Creek – RM0.3

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 mL)	Calculated Reduction to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/13/11	19.6	69.8%	66			
9/20/11	15.8	75.8%	345			
9/27/11	12.3	81.3%	649			
10/4/11	10.4	84.3%	816			
10/11/11	7.96	88.9%	96	**259**	**51.3**	**56.3**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-60. Calculated Load Reduction Based on Daily Loading – Town Creek – RM0.9

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/19/12	High Flows	56.0	9.3%	1	1.37E+09	NR	**NR**	**NR**
3/21/12	Moist-Conditions	35.6	30.7%	40	3.49E+10	NR	**NR**	**NR**
11/8/11	Mid-Range	29.0	44.6%	17	1.21E+10	NR		
5/22/12		24.2	56.6%	75	4.43E+10	NR		
9/13/11		18.6	69.8%	39	1.77E+10	NR	**NR**	**NR**
9/20/11	Low Flows	15.0	75.8%	435	1.59E+11	NR		
6/20/12		12.0	80.8%	313	9.19E+10	NR		
9/27/11		11.6	81.3%	162	4.61E+10	NR		
7/21/11		11.1	82.2%	687	1.87E+11	NR		
10/4/11		9.86	84.3%	1553	3.75E+11	**39.4**		
8/30/11		8.26	87.5%	48	9.70E+09	NR		
10/11/11		7.52	88.9%	167	3.07E+10	NR	**39.4**	**45.5**

Note: NR = No reduction required

Table E-61. Calculated Load Reduction Based on Geomean Data – Town Creek – RM0.9

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction	
					to Target GM (126 CFU/100 mL)	to Target - MOS (113 CFU/100 mL)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/13/11	18.6	69.8%	39			
9/20/11	15.0	75.8%	435			
9/27/11	11.6	81.3%	162			
10/4/11	9.86	84.3%	1553			
10/11/11	7.52	88.9%	167	**235**	**46.3**	**51.9**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-62. Summary of TMDLs, WLAs, & LAs by Flow Regime for Impaired Waterbodies in the Watauga River Watershed (HUC 06010103)

Waterbody Description (06010103____)	Hydrologic Condition: Flow Regime	Hydrologic Condition: PDFE Range	Hydrologic Condition: Flow Range	Flow[a]	PLRG	TMDL	MOS	WLAs: WWTPs[c]	WLAs: MS4s[d]	LAs[d]
		[%]	[cfs]	[cfs]	[%]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d/ac]	[CFU/d/ac]
Town Creek	High Flows	0-10	57.91 – 1,077	71.29	51.3[b]	1.640E+12	1.640E+11	($1.2 \times 10^{10} \times q_m$)	8.196E+7	8.196E+7
Waterbody ID:	Moist	10-40	32.75 – 57.91	41.57		9.561E+11	9.561E+10		4.746E+7	4.746E+7
034-0300	Mid-Range	40-60	19.51 – 32.75	26.25		6.038E+11	6.038E+10		2.967E+7	2.967E+7
HUC-12: 0101	Low Flows	90-100	0.520 – 19.51	9.97		2.293E+11	2.293E+10		1.077E+7	1.077E+7
Roan Creek	High Flows	0-10	138.6 – 2,609	168.6	NR	2.023E+12	2.023E+11	($1.2 \times 10^{10} \times q_m$)	4.219E+7	4.219E+7
Waterbody ID:	Moist	10-40	78.27 – 138.6	99.13	NR	1.190E+12	1.190E+11		2.467E+7	2.467E+7
034-2000	Mid-Range	40-60	57.79 – 78.27	67.95	NR	8.154E+11	8.154E+10		1.680E+7	1.680E+7
HUC-12s: 0102, 0104	Dry	60-90	17.41 – 57.79	38.93	67.6	4.672E+11	4.672E+10		9.485E+6	9.485E+6
	Low Flows	90-100	1.330 – 17.41	9.63	NR	1.156E+11	1.156E+10		2.094E+6	2.094E+6
Sink Branch	High Flows	0-10	2.94 – 57.30	3.57	97.9[b]	8.211E+10	8.211E+09	($2.3 \times 10^{10} \times q_m$)[e]	(8.076E+7) - ($2.514E+7 \times q_d$)[f]	(8.076E+7) - ($2.514E+7 \times q_d$)
Waterbody ID:	Moist	10-40	1.67 – 2.94	2.10		4.830E+10	4.830E+09		(4.751E+7) - ($2.514E+7 \times q_d$)[f]	(4.751E+7) - ($2.514E+7 \times q_d$)
020T-0200	Mid-Range	40-70	0.98 – 1.67	1.32		3.036E+10	3.036E+09		(2.986E+7) - ($2.514E+7 \times q_d$)[f]	(2.986E+7) - ($2.514E+7 \times q_d$)
HUC-12: 0306	Low Flows	70-100	0.030 – 0.98	0.500		1.150E+09	1.150E+08		(1.131E+7) - ($2.514E+7 \times q_d$)[f]	(1.131E+7) - ($2.514E+7 \times q_d$)
Buffalo Creek	High Flows	0-10	85.45 – 1,768	114.2	NA	2.627E+12	2.627E+11	($2.3 \times 10^{10} \times q_m$)[e]	(9.927E+7) - ($9.658E+5 \times q_d$)	(9.927E+7) - ($9.658E+5 \times q_d$)
Waterbody ID:	Moist	10-40	39.40 – 85.45	52.92	NR	1.217E+12	1.217E+11		(4.600E+7) - ($9.658E+5 \times q_d$)	(4.600E+7) - ($9.658E+5 \times q_d$)
011-1000	Mid-Range	40-70	21.31 – 39.40	30.10	NR	6.923E+11	6.923E+10		(2.616E+7) - ($9.658E+5 \times q_d$)	(2.616E+7) - ($9.658E+5 \times q_d$)
HUC-12: 0502	Low Flows	70-100	3.05 – 21.31	13.15	67.8	3.025E+11	3.025E+10		(1.143E+7) - ($9.658E+5 \times q_d$)	(1.143E+7) - ($9.658E+5 \times q_d$)

Table E-62 (cont'd). Summary of TMDLs, WLAs, & LAs by Flow Regime for Impaired Waterbodies in the Watauga River Watershed (HUC 06010103)

Waterbody Description (06010103____)	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs		LAs [d]
	Flow Regime	PDFE Range	Flow Range					WWTPs[c]	MS4s[d]	
		[%]	[cfs]	[cfs]	[%]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d/ac]	[CFU/d/ac]
Powder Branch	High Flows	0-10	11.87 – 245..6	14.82		3.409E+11	3.409E+10		(9.931E+7) - (7.446E+6 x q_d)	(9.931E+7) - (7.446E+6 x q_d)
Waterbody ID:	Moist	10-40	5.40 – 11.87	6.84	85.6b	1.573E+11	1.573E+10	(2.3×10^{10} x q_m) [e]	(4.584E+7) - (7.446E+6 x q_d)	(4.584E+7) - (7.446E+6 x q_d)
011-0100	Mid-Range	40-60	2.91 – 5.40	3.89		8.947E+10	8.947E+09		(2.607E+7) - (7.446E+6 x q_d)	(2.607E+7) - (7.446E+6 x q_d)
HUC-12: 0502	Low Flows	90-100	0.3900 – 2.91	1.69		3.887E+10	3.887E+09		(1.133E+7) - (7.446E+6 x q_d)	(1.133E+7) - (7.446E+6 x q_d)
Toll Branch	High Flows	0-10	9.12 – 208.0	12.32		2.834E+11	2.834E+10		(9.708E+7) - (8.755E+6 x q_d)	(9.708E+7) - (8.755E+6 x q_d)
Waterbody ID:	Moist	10-40	4.29 – 9.12	5.77	99.7[b]	1.327E+11	1.327E+10	(2.3×10^{10} x q_m) [e]	(4.547E+7) - (8.755E+6 x q_d)	(4.547E+7) - (8.755E+6 x q_d)
011-0200	Mid-Range	40-70	2.31 – 4.29	3.27		7.521E+10	7.521E+09		(2.577E+7) - (8.755E+6 x q_d)	(2.577E+7) - (8.755E+6 x q_d)
HUC-12: 0502	Low Flows	70-100	0.350 – 2.31	1.41		3.243E+10	3.243E+09		(1.111E+7) - (8.755E+6 x q_d)	(1.111E+7) - (8.755E+6 x q_d)
Sinking Creek	High Flows	0-10	25.73 – 505.9	38.25		8.798E+11	8.798E+10		(1.226E+8) - (3.563E+6 x q_d)	(1.226E+8) - (3.563E+6 x q_d)
Waterbody ID:	Moist	10-40	10.60 – 25.73	15.03	51.0[b]	3.457E+11	3.457E+10	(2.3×10^{10} x q_m) [e]	(4.547E+7) - (3.563E+6 x q_d)	(4.547E+7) - (3.563E+6 x q_d)
046-1000	Mid-Range	40-70	5.64 – 10.60	8.06		1.854E+11	1.854E+10		(2.584E+7) - (3.563E+6 x q_d)	(2.584E+7) - (3.563E+6 x q_d)
HUC-12: 0503	Low Flows	70-100	0.730 – 5.64	3.41		7.843E+10	7.843E+09		(1.093E+7) - (3.563E+6 x q_d)	(1.093E+7) - (3.563E+6 x q_d)
Brush Creek	High Flows	0-10	48.54 – 899.8	87.15	NR	2.004E+12	2.004E+11		(1.923E+08) - (2.452E+6 x q_d)	(1.923E+08) - (2.452E+6 x q_d)
Waterbody ID:	Moist	10-40	12.29 – 48.54	20.34	BR	4.678E+11	4.678E+10	(2.3×10^{10} x q_m) [e]	(4.489E+07) - (2.452E+6 x q_d)	(4.489E+07) - (2.452E+6 x q_d)
009-1000	Mid-Range	40-70	4.20 – 12.29	7.90	NR	1.817E+11	1.817E+10		(1.743E+07) - (2.452E+6 x q_d)	(1.743E+07) - (2.452E+6 x q_d)
HUC-12: 0504	Low Flows	70-100	0.19 – 4.20	1.88	82.5	4.324E+10	4.324E+09		(4.149E+06) - (2.452E+6 x q_d)	(4.149E+06) - (2.452E+6 x q_d)

Table E-62 (cont'd). Summary of TMDLs, WLAs, & LAs by Flow Regime for Impaired Waterbodies in the Watauga River Watershed (HUC 06010103)

Waterbody Description (06010103____)	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs		LAs[d]
	Flow Regime	PDFE Range	Flow Range					WWTPs[c]	MS4s[d]	
		[%]	[cfs]	[cfs]	[%]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d/ac]	[CFU/d/ac]
Davis Branch	High Flows	0-10	3.90 – 75.70	5.14	63.5[b]	1.182E+11	1.182E+10	$(2.3\times10^{10}$ x $q_m)$ [e]	(9.944E+7) - (2.150E+7 x q_d)	(9.944E+7) - (2.150E+7 x q_d)
Waterbody ID:	Moist	10-40	1.83 – 3.90	2.49		5.727E+10	5.727E+09		(4.817E+7) - (2.150E+7 x q_d)	(4.817E+7) - (2.150E+7 x q_d)
008-0400	Mid-Range	40-70	0.980 – 1.83	1.39		3.197E+10	3.197E+09		(2.689E+7) - (2.150E+7 x q_d)	(2.689E+7) - (2.150E+7 x q_d)
HUC-12: 0505	Low Flows	70-100	0.130 – 0.980	0.590		1.357E+10	1.357E+09		(1.141E+7) - (2.150E+7 x q_d)	(1.141E+7) - (2.150E+7 x q_d)
Gap Creek	High Flows	0-10	21.49 – 465.7	28.63	94.6[b]	6.585E+11	6.585E+10	$(2.3\times10^{10}$ x $q_m)$ [e]	(9.706E+7) - (3.767E+6 x q_d)	(9.706E+7) - (3.767E+6 x q_d)
Waterbody ID:	Moist	10-40	9.97 – 21.49	13.48		3.100E+11	3.100E+10		(4.570E+7) - (3.767E+6 x q_d)	(4.570E+7) - (3.767E+6 x q_d)
008-0800	Mid-Range	40-70	5.37 – 9.97	7.61		1.750E+11	1.750E+10		(2.580E+7) - (3.767E+6 x q_d)	(2.580E+7) - (3.767E+6 x q_d)
HUC-12: 0505	Low Flows	70-100	0.780 – 5.37	3.26		7.498E+10	7.198E+09		(1.105E+7) - (3.767E+6 x q_d)	(1.105E+7) - (3.767E+6 x q_d)
Knob Creek	High Flows	0-10	23.69 – 501.1	39.54	94.3[b]	4.745E+11	4.745E+10	$(2.3\times10^{10}$ x $q_m)$ [e]	(8.062E+7) - (4.342E+6 x q_d)	(8.062E+7) - (4.342E+6 x q_d)
Waterbody ID:	Moist	10-40	7.18 – 23.69	11.46		1.375E+11	1.375E+10		(2.337E+7) - (4.342E+6 x q_d)	(2.337E+7) - (4.342E+6 x q_d)
635-1000	Mid-Range	40-70	2.56 – 7.18	4.76		5.712E+10	5.712E+09		(9.705E+6) - (4.342E+6 x q_d)	(9.705E+6) - (4.342E+6 x q_d)
HUC-12: 0506	Low Flows	70-100	0.130 – 2.56	1.15		1.380E+10	1.380E+09		(2.345E+6) - (4.342E+6 x q_d)	(2.345E+6) - (4.342E+6 x q_d)
Cobb Creek	High Flows	0-10	13.53 – 236.1	24.71	75.0[b]	5.683E+11	5.683E+10	$(2.3\times10^{10}$ x $q_m)$ [e]	(2.160E+8) - (9.713E+6 x q_d)	(2.160E+8) - (9.713E+6 x q_d)
Waterbody ID:	Moist	10-40	2.95 – 13.53	4.94		1.136E+11	1.136E+10		(4.318E+7) - (9.713E+6 x q_d)	(4.318E+7) - (9.713E+6 x q_d)
635-0200	Mid-Range	40-70	0.900 – 2.95	1.85		4.255E+10	4.255E+09		(1.617E+7) - (9.713E+6 x q_d)	(1.617E+7) - (9.713E+6 x q_d)
HUC-12: 0506	Low Flows	70-100	0.040 – 0.980	0.450		1.035E+10	1.035E+09		(3.934E+6) - (9.713E+6 x q_d)	(3.934E+6) - (9.713E+6 x q_d)

Table E-62 (cont'd). Summary of TMDLs, WLAs, & LAs by Flow Regime for Impaired Waterbodies in the Watauga River Watershed (HUC 06010103)

Waterbody Description **(06010103____)**	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs		LAs [d]
	Flow Regime	PDFE Range	Flow Range					WWTPs[c]	MS4s[d]	
		[%]	[cfs]	[cfs]	[%]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d/ac]	[CFU/d/ac]
Cash Hollow Creek	High Flows	0-10	7.19 – 171.2	11.81	90.8[b]	2.716E+11	2.716E+10	(2.3x10^{10} x q_m) [e]	(1.352E+8) - (1.272E+7 x q_d)	(1.352E+8) - (1.272E+7 x q_d)
Waterbody ID:	Moist	10-40	2.46 – 7.19	3.76		8.648E+10	8.648E+09		(4.305E+7) - (1.272E+7 x q_d)	(4.305E+7) - (1.272E+7 x q_d)
635-0100	Mid-Range	40-70	0.900 – 2.46	1.59		3.657E+10	3.657E+09		(1.820E+7) - (1.272E+7 x q_d)	(1.820E+7) - (1.272E+7 x q_d)
HUC-12: 0506	Low Flows	70-100	0.050 – 0.900	0.830		1.909E+10	1.909E+09		(9.503E+6) - (1.272E+7 x q_d)	(9.503E+6) - (1.272E+7 x q_d)
Boones Creek	High Flows	0-10	29.61 – 611.4	38.59	95.7[b]	8.876E+11	8.876E+10	(2.3x10^{10} x q_m) [e]	(9.968E+7) - (2.870E+6 x q_d)	(9.968E+7) - (2.870E+6 x q_d)
Waterbody ID:	Moist	10-40	13.57 – 29.61	18.39		4.230E+11	4.230E+10		(4.750E+7) - (2.870E+6 x q_d)	(4.750E+7) - (2.870E+6 x q_d)
006-1000	Mid-Range	40-70	7.32 – 13.57	10.33		2.376E+11	2.376E+10		(2.668E+7) - (2.870E+6 x q_d)	(2.668E+7) - (2.870E+6 x q_d)
HUC-12: 0507	Low Flows	70-100	1.100 – 7.32	4.53		1.042E+11	1.042E+10		(1.170E+7) - (2.870E+6 x q_d)	(1.170E+7) - (2.870E+6 x q_d)
Carroll Creek	High Flows	0-10	6.41 – 128.5	9.48	NR	2.180E+11	2.180E+10	(2.3x10^{10} x q_m) [e]	(1.248E+8) - (1.462E+7 x q_d)	(1.248E+8) - (1.462E+7 x q_d)
Waterbody ID:	Moist	10-40	2.62 – 6.41	3.71	NR	8.533E+10	8.533E+09		(4.882E+7) - (1.462E+7 x q_d)	(4.882E+7) - (1.462E+7 x q_d)
006-0100	Mid-Range	40-60	1.37 – 2.62	1.97	NR	4.531E+10	4.531E+09		(2.582E+7) - (1.462E+7 x q_d)	(2.582E+7) - (1.462E+7 x q_d)
HUC-12: 0507	Low Flows	90-100	0.170 – 1.37	0.830	61.1	1.909E+10	1.909E+09		(1.143E+7) - (1.462E+7 x q_d)	(1.143E+7) - (1.462E+7 x q_d)
Darr Creek	High Flows	0-10	5.17 – 114.7	6.97	85.2[b]	1.603E+11	1.603E+10	(2.3x10^{10} x q_m) [e]	(9.716E+7) - (1.549E+7 x q_d)	(9.716E+7) - (1.549E+7 x q_d)
Waterbody ID:	Moist	10-40	2.43 – 5.17	3.25		7.475E+10	7.475E+09		(4.530E+7) - (1.549E+7 x q_d)	(4.530E+7) - (1.549E+7 x q_d)
001T-0100	Mid-Range	40-70	1.30 – 2.43	1.85		4.255E+10	4.255E+09		(2.579E+7) - (1.549E+7 x q_d)	(2.579E+7) - (1.549E+7 x q_d)
HUC-12: 0508	Low Flows	70-100	0.190 – 1.30	0.790		1.817E+10	1.817E+09		(1.101E+7) - (1.549E+7 x q_d)	(1.101E+7) - (1.549E+7 x q_d)

Table E-62 (cont'd). Summary of TMDLs, WLAs, & LAs by Flow Regime for Impaired Waterbodies in the Watauga River Watershed (HUC 06010103)

Waterbody Description (06010103____)	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs		LAs[d]
	Flow Regime	PDFE Range	Flow Range					WWTPs[c]	MS4s[d]	
		[%]	[cfs]	[cfs]	[%]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d/ac]	[CFU/d/ac]
Reedy Creek	High Flows	0-10	11.87 – 248.5	15.77	65.7^b	3.627E+11	3.627E+10	$(2.3\times10^{10}$ x $q_m)^e$	(9.974E+7) - (7.027E+6 x q_d)	(9.974E+7) - (7.027E+6 x q_d)
Waterbody ID:	Moist	10-40	5.40 – 11.87	7.33		1.686E+11	1.686E+10		(4.636E+7) - (7.027E+6 x q_d)	(4.636E+7) - (7.027E+6 x q_d)
061-1000	Mid-Range	40-70	2.91 – 5.40	4.13		9.499E+10	9.499E+09		(2.611E+7) - (7.027E+6 x q_d)	(2.611E+7) - (7.027E+6 x q_d)
HUC-12: 0508	Low Flows	70-100	0.390 – 2.91	1.78		4.094E+10	4.094E+09		(1.126E+7) - (7.027E+6 x q_d)	(1.126E+7) - (7.027E+6 x q_d)

Notes: NA = Not Applicable.
NR = No Reduction Required.
PLRG = Percent Load Reduction Goal to achieve TMDL.
q_m = Mean Daily WWTP Discharge (cfs)
q_d = Facility (WWTP) Design Flow (cfs)
Shaded Flow Zone for each waterbody represents the critical flow zone.

a. Flow applied to TMDL, MOS, and allocation (WLA[MS4] and LA) calculations. Flows represent the midpoint value in the respective hydrologic flow regime.
b. PLRG based on geomean data.
c. WLAs for WWTPs are expressed as E. coli loads (CFU/day). All current and future WWTPs must meet water quality standards as specified in their NPDES permit.
d. WLAs and LAs expressed on a "per acre" basis are calculated based on the drainage area at the specific monitoring point (see Table E-3). As regulated MS4 area increases (due to future growth and/or new MS4 designation), unregulated LA area decreases by an equivalent amount. The sum will continue to equal total subwatershed area.
e. No WWTPs currently discharging into or upstream of the waterbody. (Expression is future growth term for new WWTPs.)
f. No MS4s currently located in the subwatershed drainage area. (Expression is future growth term for expanding or newly designated MS4s.)

APPENDIX F

Trend Analysis for Waterbodies Impaired by E. coli in the Watauga River Watershed

In the Watauga River watershed, periods of record greater than 5 years (given adequate sampling frequency) were evaluated for trend analysis. For watersheds in second or successive TMDL cycles, data collected from multiple cycles were compared. If implementation efforts have been initiated to reduce loading, evaluation of routine monitoring data may indicate improving or worsening conditions over time and corresponding effectiveness of implementation efforts.

Water quality data for implementation effectiveness analysis can be presented in multiple ways. Several examples are shown in Section 9.6. Load duration curve methodology is most appropriate when monthly monitoring data, representative of all flow regimes, have been collected. However, in the Watauga River Watershed, both monthly data and geomean data (5 or more samples in a 30-day period) are available for analysis. Therefore, box and whisker plots have been selected as the most appropriate method of presenting the monitoring data. Data intended for geomean analysis (identified by "GM" in the plots) are grouped together for each specific 30-day period and the maximum geomean within that 30-day period is represented by a red dot. Data covering a period greater than 30 days (typically monthly samples) are grouped together by sampling cycle, a 12-month period usually not coincident with the calendar year. In this case, the mean of the data is represented by a white diamond.

Three waterbodies, Darr Creek (TN06010103001T-0100), Powder Branch (TN06010103011-0100), and Toll Branch (TN06010103011-0200) were not included in this trend analysis due to insufficient monitoring data. All of the monitoring data for these three waterbodies were from one sampling cycle (2011-2012).

F.1 Worsening Trends

Based on analysis of data from 2006 thru 2012, the condition of **Davis Branch** (TN06010103008-0400) appears to be deteriorating slightly (Figure F-1). There were two exceedances of the single sample maximum criterion during both the 2006/2007 sampling cycle and the 2011/2012 sampling cycle. However, the average and maximum values are slightly higher during the 2011/2012 sampling cycle than during the 2006/2007 sampling cycle. Geomean samples were only collected during September 2011 and the calculated geomean value exceeded the geomean criterion. Exceedances occurred during a variety of flow conditions, suggesting that Davis Branch may be impaired by both point-type and nonpoint-type sources.

Based on analysis of data from 2006 thru 2012, the condition of **Gap Creek** (TN06010103008-0800) appears to be deteriorating (Figure F-2). The samples collected at stations GAP000.1CT and GAP000.4CT during 2006 and 2007 show some variation, but 5 of the 21 sample values exceeded the single sample maximum criterion. Fewer monthly samples (12) were collected at GAP000.1CT during 2011 and 2012, but there were a greater number of exceedances (7) than during the 2006/2007 sampling period. The geomean samples collected at station GAP000.1CT during September 2011 are significantly worse than the previous geomean samples collected during September/October 2006. The geomean samples collected in 2006 did not include any exceedances of the single sample maximum criterion, while 5 of the 6 geomean samples collected in 2011 exceeded the single sample maximum criterion.

Based on analysis of data from 2006 thru 2012, the condition of **Sink Branch** (TN06010103020T-0200) appears to be deteriorating (Figure F-3). The geomean of the samples collected in September/October 2011 is more than an order of magnitude greater than the geomean of the samples collected in April 2007.

Based on analysis of data from 2001 thru 2012, the condition of **Town Creek** (TN06010103034-0300) appears to be deteriorating. (Figure F-4) There were no exceedances of the single sample maximum criterion during either the 2001/2002 or the 2006/2007 sampling cycle. There was only exceedance of the single sample maximum criterion occurred in October 2011, but the other sample values were high enough that the geomean criterion was also exceeded in October 2011.

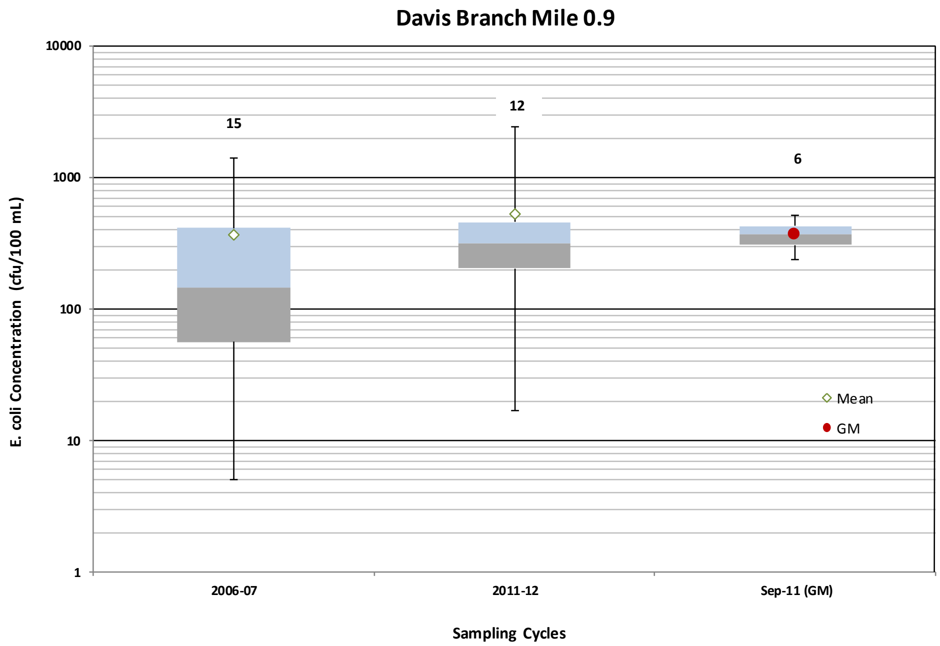

Figure F-1. Box and Whisker Plot for Davis Branch – RM0.9

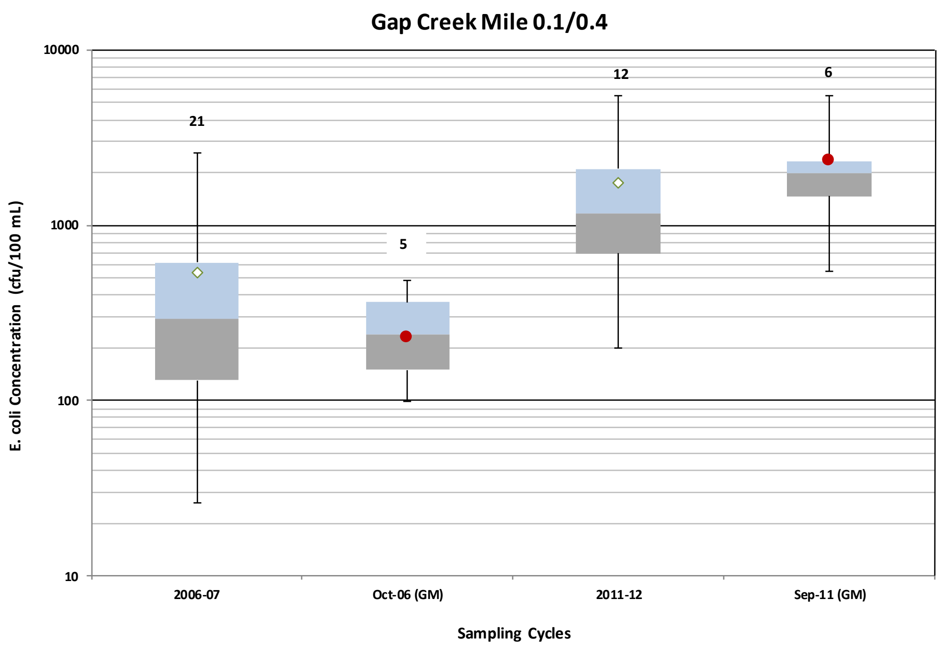

Figure F-2. Box and Whisker Plot for Gap Creek – RM0.1 & 0.4

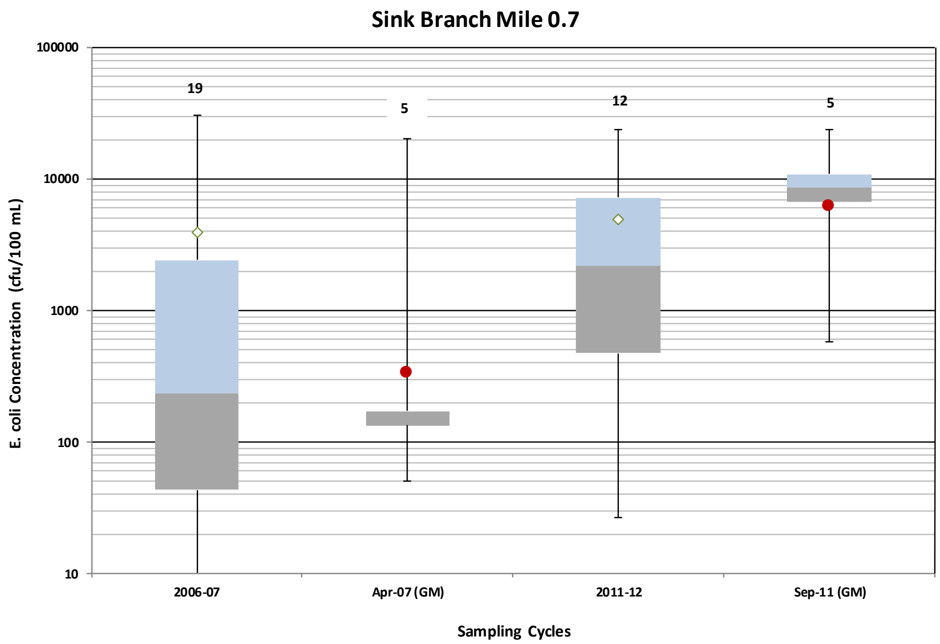

Figure F-3. Box and Whisker Plot for Sink Branch – RM0.7

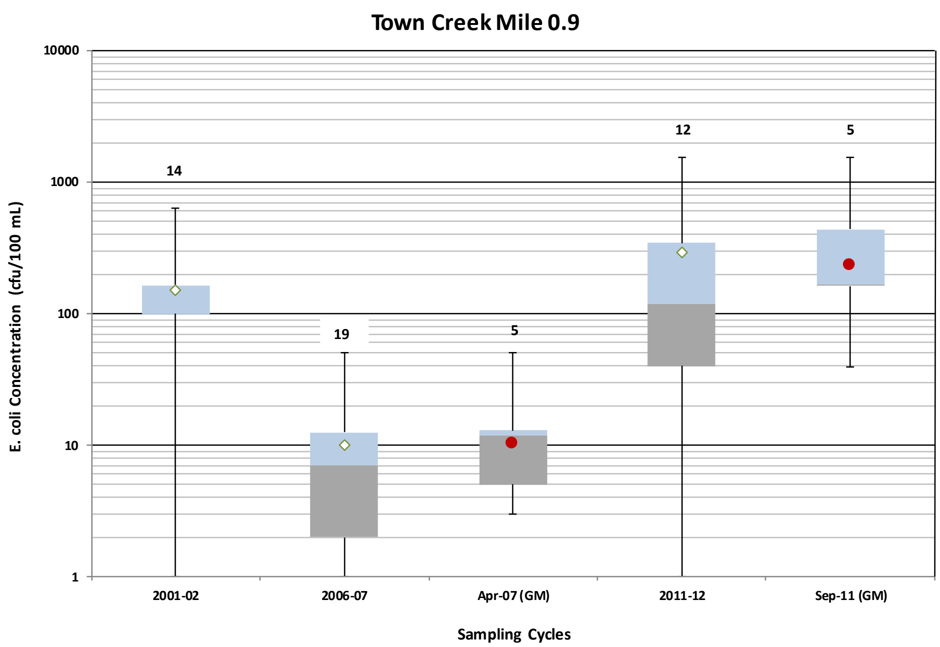

Figure F-4. Box and Whisker Plot for Town Creek – RM0.9

F.2 Improving Trends

Based on analysis of data from 2006 thru 2012, the condition of **Carroll Creek** (TN06010103006-0100) appears to indicate minor improvement (Figure F-5). Although there are still exceedances of the single sample maximum criterion and geomean criterion, the exceedances were fewer and of lesser magnitude.

Based on analysis of data from 2006 thru 2013, the condition of **Reedy Creek** (TN06010103061-1000) appears to be improving (Figure F-6). Although there are still exceedances of the single sample maximum criterion and geomean criterion, the exceedances of the single sample maximum criterion are fewer (2 vs 16) and the exceedance of the geomean criterion is almost an order of magnitude lower.

Based on analysis of data from 2001 thru 2012, the condition of **Roan Creek** (TN06010103034-2000) at mile 11.8 has improved (Figure F-7). There are no exceedances of the single sample maximum criterion during the 2011/2012 sampling cycle. However, the geomean of the samples collected during September/October 2011 exceeded the geomean criterion. Continued emphasis on the lower flow regimes and point-type sources is recommended.

Based on analysis of data from 2001 thru 2012, the condition of **Roan Creek** (TN06010103034-2000) at mile 18.2 has improved (Figure F-8). There are no exceedances of either the single sample maximum criterion or the geomean criterion during the 2011/2012 sampling cycle. While the results of analysis at mile 18.2 would suggest possible de-listing, the results of analysis at mile 16.6 do not confirm this recommendation.

Based on analysis of data from 2001 thru 2012, the condition of **Roan Creek** (TN06010103034-2000) at mile 16.6 has improved (Figure F-9). However, there are still exceedances of the single sample maximum criterion and the geomean criterion. Continued emphasis on the lower flow regimes and point-type sources is recommended.

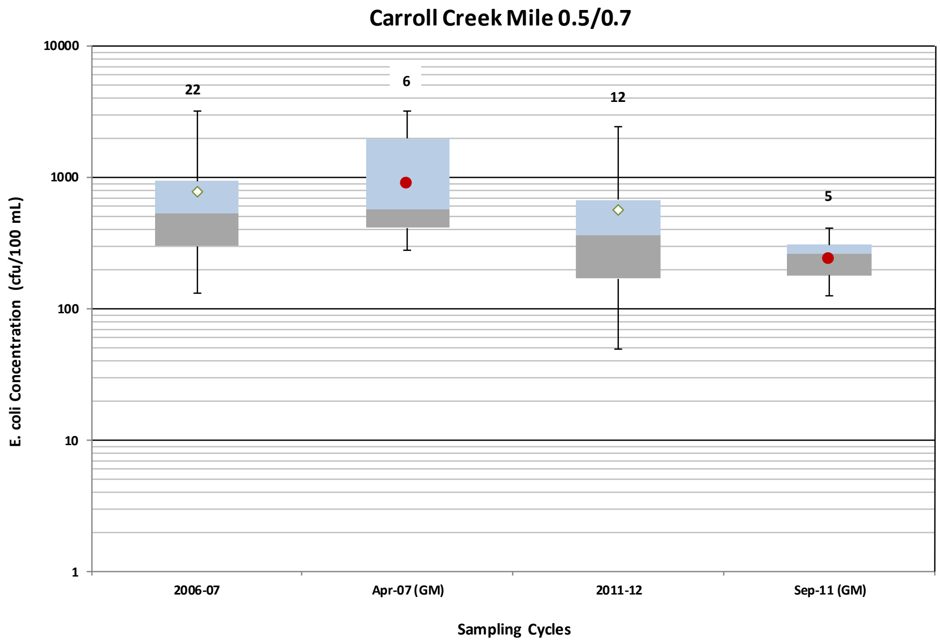

Figure F-5. Box and Whisker Plot for Carroll Creek – RM0.5/0.7

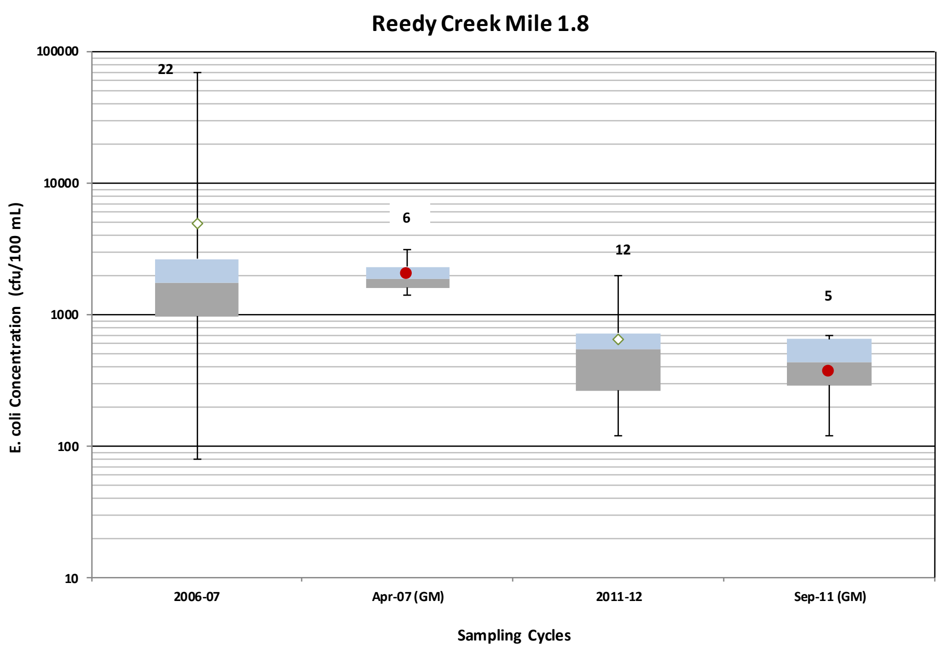

Figure F-6. Box and Whisker Plot for Reedy Creek – RM1.8

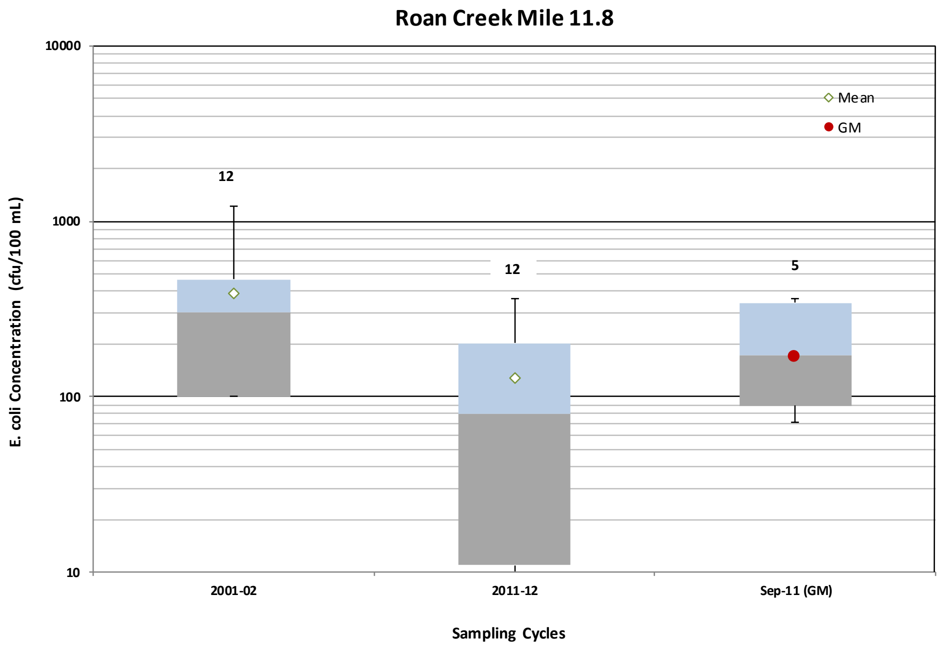

Figure F-7. Box and Whisker Plot for Roan Creek – RM11.8

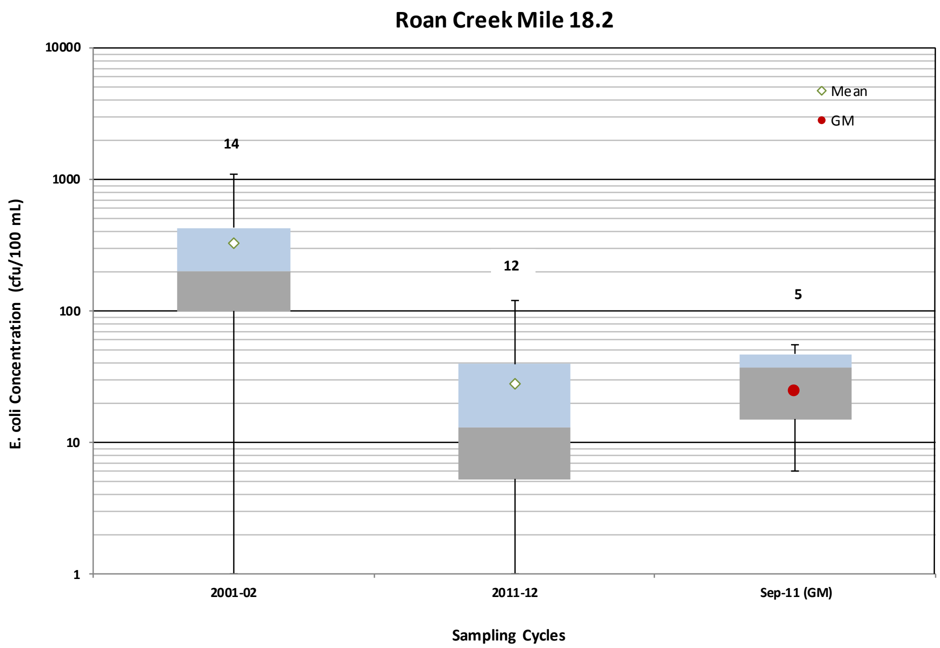

Figure F-8. Box and Whisker Plot for Roan Creek – RM18.2

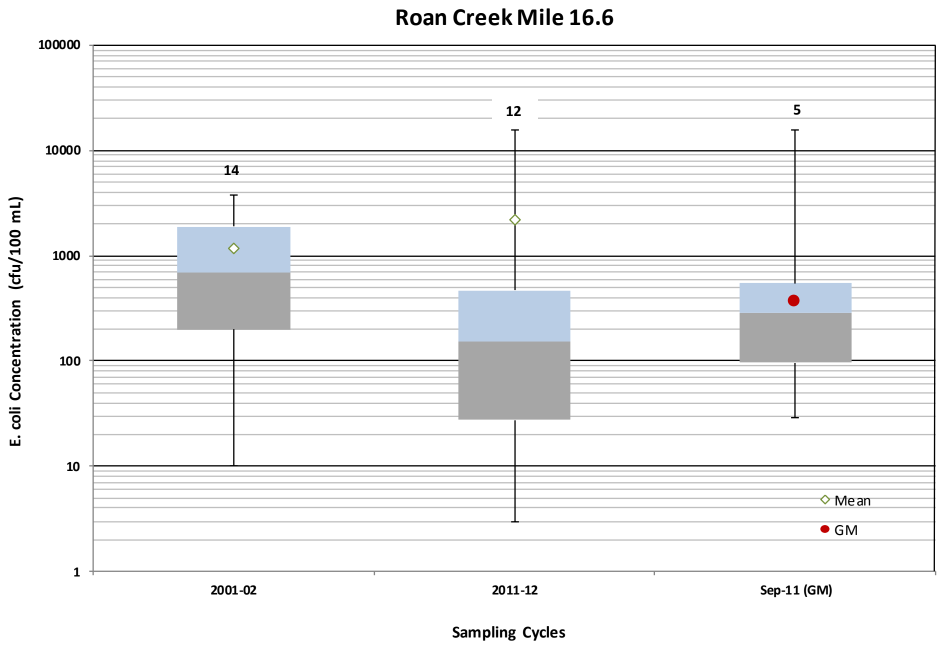

Figure F-9. Box and Whisker Plot for Roan Creek – RM16.6

F.3 Ambiguous Conditions

Based on analysis of data from 2006 thru 2012, the condition of **Boones Creek** (TN06010103006-1000) appears ambiguous (Figures F-10 and F-11). All monitoring stations on Boones Creek recorded exceedances of both the single sample maximum criterion and the geomean criterion. At the upstream stations (BOONE003.7WN and BOONE007.6WN), only one sample each was below the single sample maximum criterion during the 2011/2012 sampling cycle. The geomean of the samples collected in September/October 2011 was more than an order of magnitude above the geomean criterion. Samples collected further downstream (BOONE000.7WN and BOONE001.7WN) were slightly better than those collected upstream.

Based on analysis of data from 2006 thru 2012, the condition of **Brush Creek** (TN06010103009-1000) appears ambiguous (Figure F-21). While there is only one exceedance of the single sample maximum during the 2011/2012 sampling cycle, that exceedance is greater than any of the 3 exceedances which occurred during the 2006/2007 sampling cycle. Also, the exceedance in 2011 occurred during low flow conditions, while the exceedances in 2006/2007 occurred during mid-range and moist flow conditions. The monitoring data does not suggest any particular trend. Samples collected at BRUSH006.1 during May/June 2012 were all below the single sample maximum criterion and the geomean criterion, suggesting that the source of the impairment is downstream of mile 6.1.

Based on analysis of data from 2006 thru 2012, the condition of **Buffalo Creek** (TN06010103011-1000) appears ambiguous (Figure F-13). There was only one exceedance of the single sample maximum criterion at mile 0.2 during the 2011/2012 sampling cycle, compared to no exceedances during the 2006/2007 sampling cycle. However, the geomean values for April/May 2007 and August/September 2011 were virtually identical. Additional sampling occurred at miles 5.5 and 6.3 during the 2006/2007 sampling cycle, but was not repeated during the 2011/2012 sampling cycle. During the 2006/2007 sampling cycle, numerous exceedances of the single sample maximum criterion occurred at BUFFA005.5CT, while there were no exceedances at BUFFA006.3CT. This suggests that one or more sources may exist between mile 5.5 and mile 6.3. Further investigation is recommended.

Based on analysis of data from 1999 thru 2012, the condition of **Cash Hollow Creek** (TN06010103635-0100) appears ambiguous (Figures F-14 and F-15). Exceedances of the single sample maximum criterion and the geomean criterion occurred at both mile 0.3 and mile 2.7. Average, maximum, and geomean values for station CASH_G0.3WN during the 2011/2012 sampling cycle were greater than the average and geomean values for the 1999/2000 sampling cycle. However, at CASH_G2.7WN the maximum values for the 2011/2012 sampling cycle were lower than the maximum values for the 1999/2000 sampling cycle and there were no exceedances of the single sample maximum criterion during the 2011/2012 sampling cycle. This suggests that conditions at mile 2.7 may be improving while conditions at mile 0.3 appear to be worsening.

Based on analysis of data from 2006 thru 2012, the condition of **Cobb Creek** (TN06010103635-0200) appears ambiguous (Figure F-16). Although there were no exceedances of the single sample maximum criterion at COBB000.1WN during the 2006/2007 sampling cycle, two exceedances occurred during the 2011/2012 sampling cycle. Exceedances occurred on the same sample dates at COBB001.0WN. In both cases, the measured values were higher at the upstream station. Additional monitoring at station COBB001.0WN is recommended because the potential source is likely to be upstream of COBB001.0WN.

Based on analysis of data from 2006 thru 2012, the condition of **Knob Creek** (TN06010103635-1000) appears ambiguous. (Figures F-17 and F-18) Exceedances of the single sample maximum criterion and the geomean criterion occurred at all locations. Conditions appear to be worsening at KNOB001.0WN and KNOB003.7WN, while conditions appear to be improving at KNOB005.8WN. The monitoring data collected at station KNOB007.1WN does not suggest any particular trend. Sampling at this location during the 2011/2012 sampling cycle included several instances of values ">2400" or ">2420". The lack of dilution can mask the magnitude of the values and makes determination of a trend difficult. Future E. coli sample analyses at this site should follow established protocol (see Section 9.4.) Exceedances at all locations occurred during multiple flow regimes, suggesting that multiple sources may need to be addressed.

Based on analysis of data from 1999 thru 2012, the condition of **Sinking Creek** (TN06010103046-1000) appears ambiguous (Figure F-19). Exceedances of the single sample maximum criterion and the geomean criterion occurred during both sampling cycles. The average, maximum, and geomean values are slightly higher during the 2011/2012 sampling cycle. Most exceedances of the single sample maximum were identified during low flow conditions, so emphasis on point-type sources is recommended.

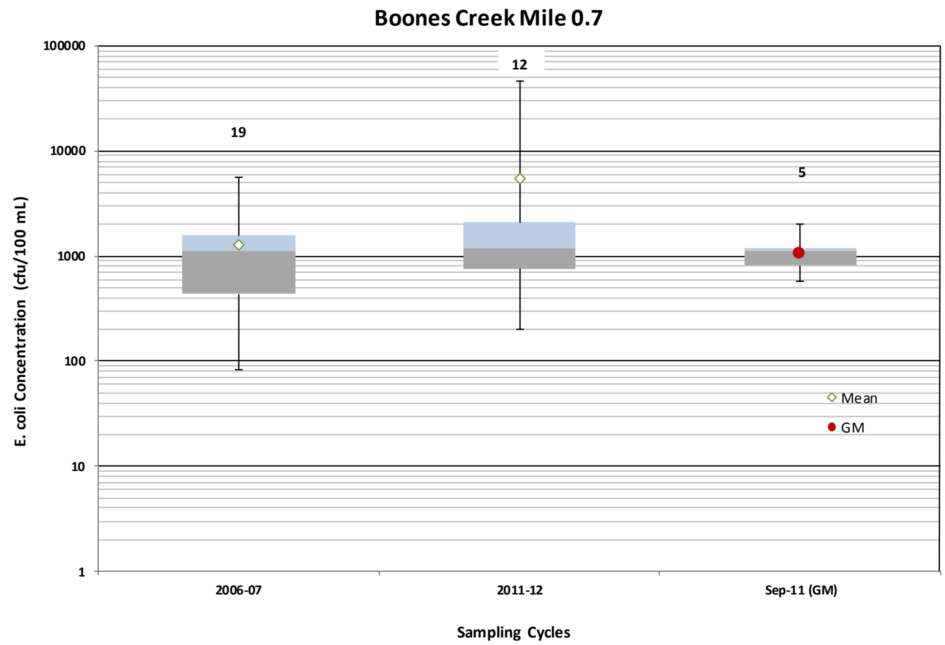

Figure F-10. Box and Whisker Plot for Boones Creek – RM0.7

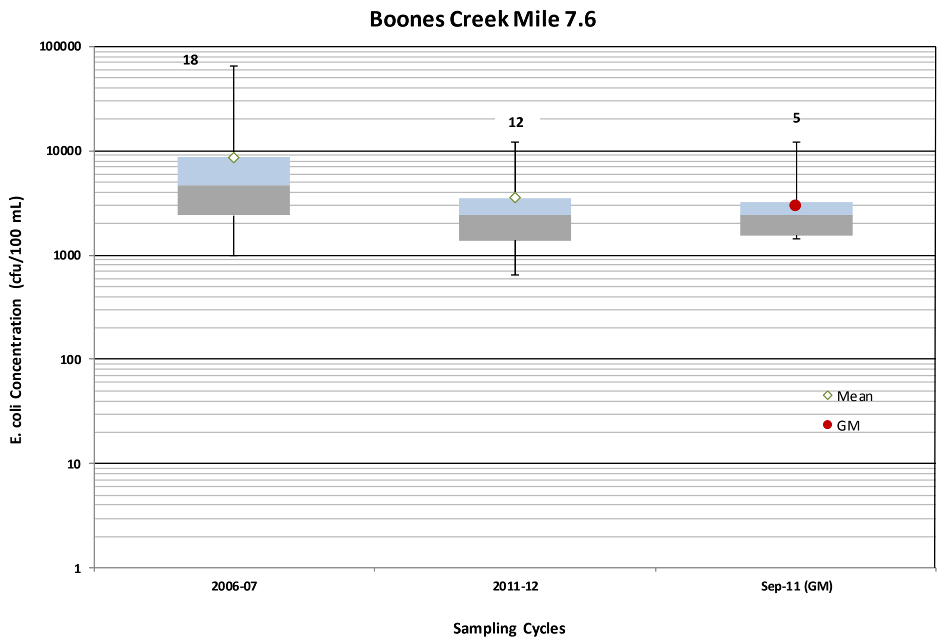

Figure F-11. Box and Whisker Plot for Boones Creek – RM7.6

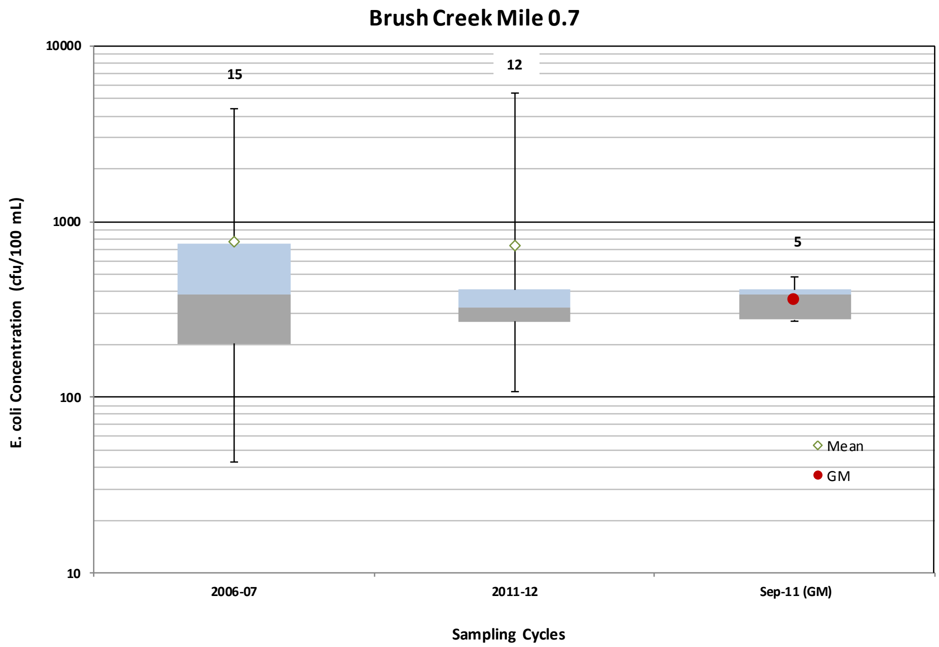

Figure F-12. Box and Whisker Plot for Brush Creek – RM0.7

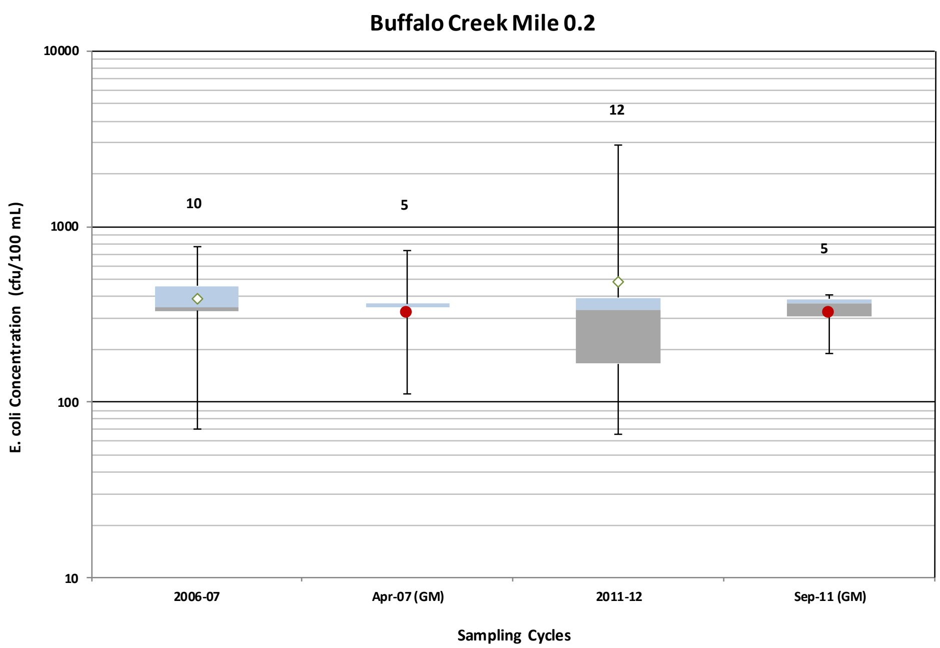

Figure F-13. Box and Whisker Plot for Buffalo Creek – RM0.2

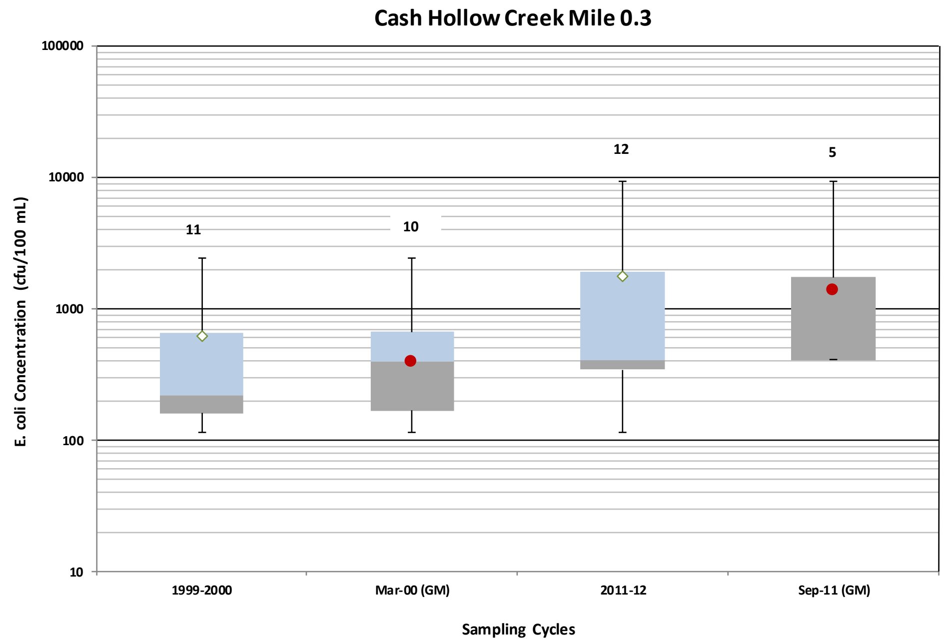

Figure F-14. Box and Whisker Plot for Cash Hollow Creek – RM0.3

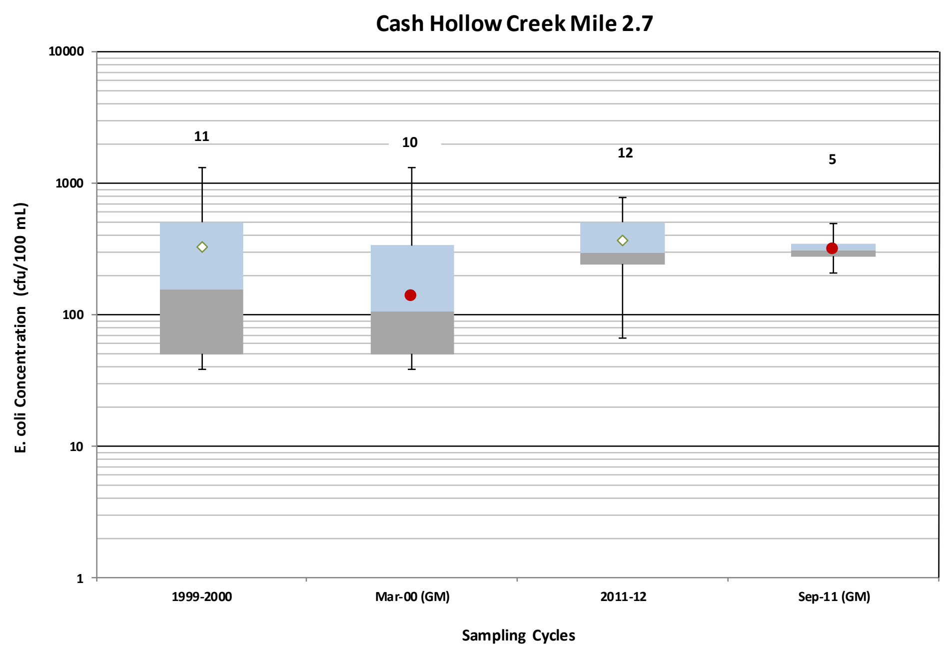

Figure F-15. Box and Whisker Plot for Cash Hollow Creek – RM2.7

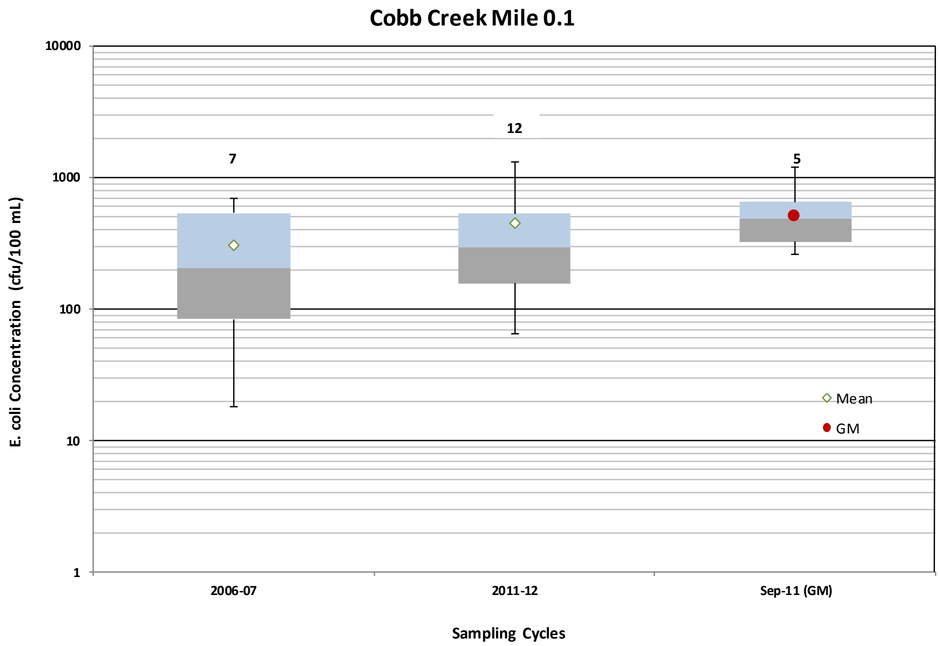

Figure F-16. Box and Whisker Plot for Cobb Creek – RM0.1

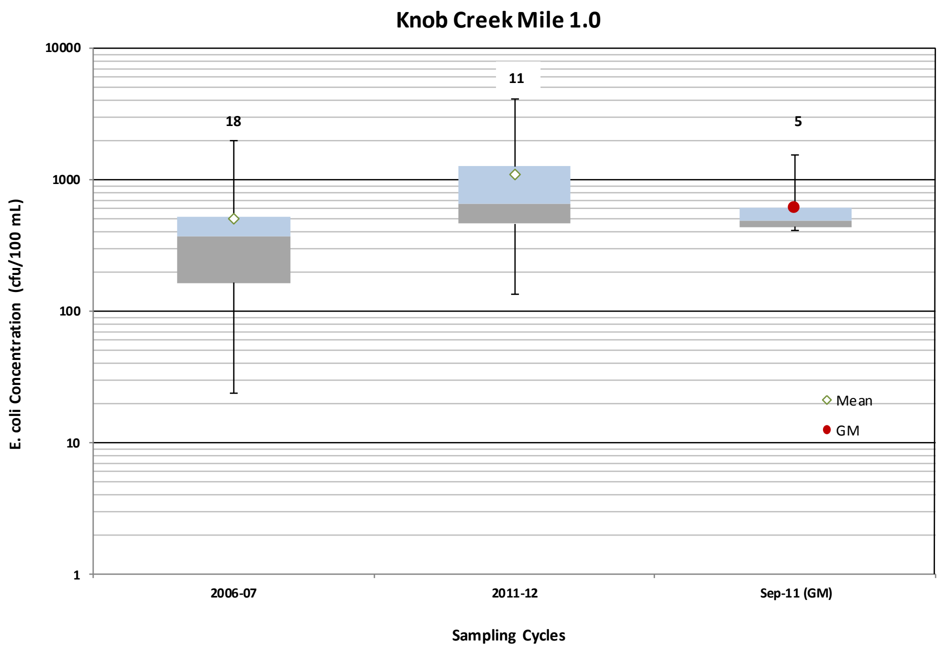

Figure F-17. Box and Whisker Plot for Knob Creek – RM1.0

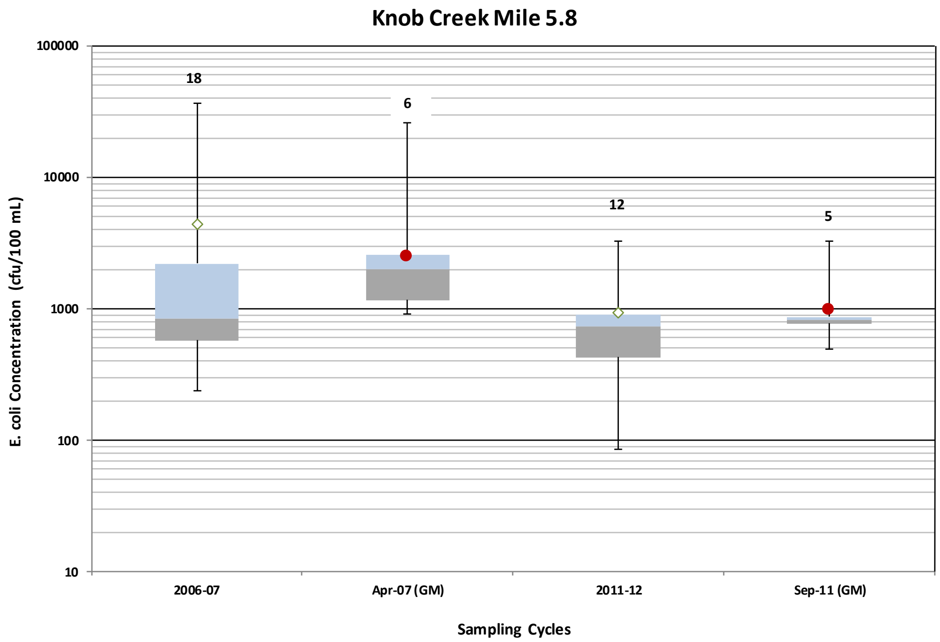

Figure F-18. Box and Whisker Plot for Knob Creek – RM5.8

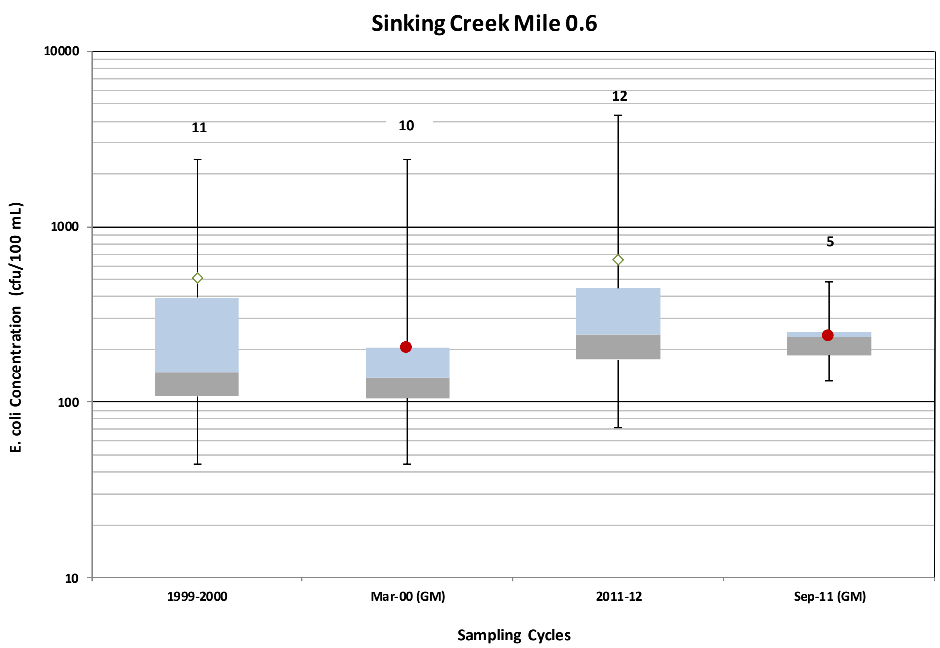

Figure F-19. Box and Whisker Plot for Sinking Creek – RM0.6